Final Project Report

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Abstract

The scope of Project 05.06.01 was investigation of the concept of Controlled Time of Arrival (CTA), aiming at using airborne technology and capability to improve ground arrival management, in a Medium/Medium traffic environment.

The project considered airborne capability currently available on some airframes and also developing airborne capability (system-to-system datalink, airborne information transmitted to the ground and enhanced flight management system functionality) expected through the emerging 'i4D'.

The concept was validated in a series of simulations (human-in-the-loop and fast-time), flight-trials (wide-spread trials involving airlines, and also trials with dedicated i4D aircraft) and Expert Group meetings/discussions.

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Acronyms

Acronym	Definition
AMAN, E-AMAN	Arrival Manager, Extended Arrival Manager
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CTA	Controlled Time of Arrival
EPP	Extended Projected Profile
ETA	Estimated Time of Arrival
FMS	Flight Management System
FTS	Fast Time Simulation
i4D	Initial Four Dimensions
INTEROP, IOP	Interoperability Requirements
MED	Medium
OI	Operational Improvement
OSED	Operational Service and Environment Definition
RTA	Required Time of Arrival
RTS	Real Time Simulation
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SPR	Safety and Performance Requirements
STAR	Standard Arrival Route
TMA	Terminal Control Area
VALP	Validation Plan
VALR	Validation Report
VP	Verification Plan

1 Project Overview

Project 05.06.01 investigated, mainly through simulations, flight-trials and Expert Group discussions, the concept of Controlled Time of Arrival (CTA) in a medium density / complexity environment.

It operated within the area of SESAR investigations that covered “Enhanced Arrival and Departure Management in TMA and En route” and it contributed towards the development of SESAR Solution #06 "Controlled Time of Arrival (CTA) in Medium density / Medium complexity environment".

1.1 Project progress and contribution to the Master Plan

The better integration/use of airborne technology in ground-sequencing, and a greater focus on Airspace User needs, are considered key elements in the transition, within SESAR, to performance based operations. The concept of CTA - as captured in SESAR Solution #06 - addresses both of these elements.

Building from previous work conducted pre-SESAR (e.g. ERAT [17] and CASSIS [16]) the investigation of the concept (from both airborne- and ground-perspectives) was conducted mainly within 05.06.01, although various other third-level and federating SESAR projects also contributed to the concept development when CTA formed part of their validations into their own Airborne, En Route, E-AMAN, and/or i4D aspects.

The central method of validation used was Human-in-the Loop Real Time Simulation (RTS). Platforms used during the various RTS validations were developed iteratively and in close cooperation with technical projects, transversal projects and air- and ground-system developers.

Several Model-based or Fast Time Simulations (FTS) were also conducted during the project's lifetime, investigating potential benefits of CTA, including the increased predictability potentially offered by the concept.

Wide-scale flight trials were conducted with aircraft equipped with some RTA functionality currently available. Two flight trials were also carried out with aircraft equipped with i4D RTA functionality (validating i4D airborne and ground requirements).

In parallel, an Expert Group was maintained within the project, comprised of operational (ANSP/ATC and Airspace Users), and technical (airborne and ground industry) representatives. The group provided an additional forum for CTA topics/issues to be identified and discussed.

Dataset 15 [18] was used by the project and referenced appropriately in the project material.

At project close the concept was considered to have reached V3 maturity level.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
TS-0103	Controlled Time of Arrival (CTA) in Medium Density/Complexity Environment	Assessment of operational improvement through various Validation Exercises, Flight trials and other activities	V2	V3

1.2 Project achievements

In reporting the main project achievements and results below, it should be noted that in some cases specific results came from specific exercises (e.g. potential fuel savings) and in other cases results were captured, or were confirmed, over the course of several validations (e.g. the capture of ATCO experiences, views and needs reported across several different RTS).

As appropriate, both qualitative and quantitative results were gathered from the various different validation activities as they were performed and these, along with the discussions held by the Expert Group, iteratively fed the discussion and development of other project deliverables, such as subsequent validation plans and the project's OSED, SPR and INTEROP, through each of their various iterations.

In general, results from across the various activities conducted in support of Solution #06 indicate that when an arrival time constraint is required for a flight, the following factors should be considered:

Environmental sustainability (fuel efficiency) can be increased if the aircraft systems are allowed to self-manage the energy of the flight to the AMAN time constraint, rather than when management is done by ATCO implementation of AMAN constraints/advisories. One exercise indicated that a fuel efficiency gain of up to 10% for CTA arrivals in the segment covered by the E-AMAN might be possible.

Delivery of the aircraft to its time constraint over a fix has been seen to be more accurate and predictable when given to the aircraft systems to achieve, rather than when delivery is done by ATCO implementation of AMAN constraints/advisories. For i4D aircraft delivery accuracy/reliability is guaranteed ±10 seconds 95% of the time, (for cases defined in ED75D/DO236C Change1), and for aircraft with current FMS technology delivery, although not guaranteed, was seen to be within ±30 seconds around 85% of the time (Wide-scale flight trials)

In terms of SESAR predictability (planned time vs achieved time) FTS results indicated a potential for a (small) reduction in variability in airborne operations, but this relates only to the portion of the flight contained within the extended AMAN horizon, not to the entire flight.

Airborne trajectory information (e.g. ETA Min/Max and EPP) was confirmed by the validation set-up teams, and by the ATCOs in several RTS validations, as being potentially very useful for the CTA concept, although some general issues with EPP were also recorded (e.g. long distances between points, weather accuracy/impact).

The project activities confirmed that there is a limit to the amount of time that an aircraft can gain/lose by speed management alone in order to meet a CTA, and that this needs to be considered when considering CTA operations – at 200 miles distance from the CTA fix the ETA 'window' available is generally around 7 minutes wide, although this is also dependent on several other factors.

The project has also seen that the natural or 'unconstrained ETA' for the flight, determined by its desired Cost Index, and the relationship between that and the location of any CTA within the aircraft's ETA Min/Max capability, will be significant. Slow flying aircraft (with low/single-digit CI) will have little capacity to slow down further in order to meet a CTA, and operationally may not wish to fly faster (and burn more fuel) to meet a CTA.

Even in medium density traffic flows, it may not always be possible for all aircraft that are capable of flying to a CTA to be offered one. Several RTS and also one FTS indicated around 65% to 75% of aircraft capable of flying a CTA as getting one. This inability to offer a CTA to all flights was the result of different factors - the required AMAN time for the flight lying outside the aircraft's capability to achieve through speed manipulation only, or to traffic circumstances at the time not permitting the En Route ATCO to allow the 'free-speed management' that is associated with CTA.

The uncertainty of each aircraft's behaviour when given a CTA (e.g. what speed each individual aircraft will target and start to fly to, when/if the RTA function is engaged in the FMS) has been noted in several RTS as a potentially significant operational issue for ATC. This issue is not solved by having new-generation RTA capability or by having EPP and/or ETA Min/Max data available from the flight (such as that provided by i4D aircraft). An airborne 'What-if', whereby the ground might interrogate or ascertain from the flight what speed it might target if given a particular CTA, is currently not on the development path for FMS, but 'white papers' have also been presented at Standardisation groups

(WG85) indicating a possible method of approximation of the speed change by the ground system – a possible ground 'What-if". This method of ground approximation has not been tested by the project.

All human-in-the-loop validations confirmed that CTA operations bring changes to the ATC workload, and to the type of workload, experienced by ATCOs. Some of the workload associated with arrival management operations was seen to move from TMA to En Route Ops, diminishing workload in TMA but increasing it in En Route. The 'Hands-off' approach to CTA flights (e.g. facilitating speed control and constraint management by aircraft systems rather than by direct ATCO 'control/intervention') was seen to decrease ATCO physical workload but, on the other hand, in some validations increased 'mental/monitoring' workload was also reported. These results, however, may need to be viewed as part of the overall move towards a more 'monitoring' role for ATCOs in the future.

CTA operations are not intended to target a specific capacity increase, but all validations have suggested that in a Medium/Medium environment at least, capacity can normally be maintained while conducting CTA operations.

The project activities also confirmed that significant automation and potentially significant upgrades to ground-based automation (especially AMAN, ground-ground messaging and Controller Working Positions) are required for the concept to operate effectively from the ATC side

CTA is not yet implemented but the conclusions and recommendations from the project activities have been reported across validation reports, are summarised within the Expert Group report, are again briefly summarised in section 1.5 of this report and are already considered by several SESAR 2020 participants in preparing future work on CTA.

1.3 Project Deliverables

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

Reference	Title	Description
D60 [5]	EXE-05.06.01-VP-203 - Interim report	EXE-203 consisted of an i4D flight trial, performed with an Airbus A320 test aircraft. The validation focused on the ability of the aircraft and ground system to share / synchronise airborne and ground trajectories, and on the use of CTA.
D64 [7]	EXE-05.06.01-VP-205 - Validation Report	EXE-205 was a set of wide scale CTA flight trials. 90 flight trials were performed with revenue flights evaluating current FMS RTA functionality, behaviour and accuracy.
D80 [10]	EXE-05.06.01-VP-326 - Validation Report	EXE-326 was the second RTS exploring the use of the i4D and CTA concepts applied in a Stockholm-Arlanda environment. The main focus was on investigating the usability of CTA and i4D, as well as the acceptability of ATCO procedures
D101 [11]	EXE-05.06.01-VP-477 - Validation Report	EXE-477 was the third and last RTS in P05.06.01. The main scope was to address some specific conceptual issues, as well as the impact on KPAs for predictability and environment/fuel efficiency. The exercise included upgraded system support previously identified as needed for the concept.
D82 [12]	EXE-05.06.01-VP-478 - Validation Report	EXE-478 was the second i4D flight trial, performed with the Airbus A320 test aircraft. The validation addressed upgraded FMS system functionality and ground system improvements.
D84 [14]	P05.06.01 Deliverable - Step 1 - fully validated SPR	Safety and Performance Requirements supporting SESAR Solution#6
D85 [15]	P05.06.01 Deliverable - Step 1 - fully validated INTEROP	Interoperability requirements supporting SESAR Solution#6

1.4 Contribution to Standardisation

Validation activities conducted in P05.06.01 have included flight trials and simulations which included i4D aircraft.

Results obtained in the flight trials and in the simulations have been used as information, and have contributed towards the functional and performance requirements being defined and developed in EUROCAE/RTCA working groups WG78 and WG85, for air/ground datalink and aircraft navigation capabilities (i4D)

1.5 Project Conclusion and Recommendations

Project Overall Conclusion:

The project has concluded that CTA in a MED/MED environment is operationally and technically feasible.

The project, through the flight trials and through simulations, has also confirmed the general feasibility and operability of the concept across ATSU boundaries, although some elements of the future ground/ground messaging to fully support this are still not fully developed.

No 'blocking issues' have been identified for the concept/solution, however the project considers that further development is likely required to enhance some aspects of the operation, even in the tested environment.

For instance, although the concept indeed could be implemented in the near future in a quite medium/medium environment, improved system support may help the ATCO to give more CTAs to more flights, especially when potential CTA flights are flying close together. An increased number of i4D-capable flights, with greater interaction and information exchanges between them and the ground might also make for a 'better solution'.

Further development will also most probably be essential to move the concept to a high density and/or high complexity operation.

Project Main Recommendations:

CTA-related development:

Some areas for further work might include:

There is a need to develop mitigations, as far as is possible, to some of the uncertainties inherent in the CTA operation, including the uncertainty over what speed the aircraft might target when RTA is actually engaged in the FMS. This is especially relevant if contemplating CTA operations in traffic situations where aircraft are in close proximity to each other (e.g. an isolated busy flow/situation in MED/MED, or a HIGH/HIGH operation).

- In the shorter term, developments in ground tools to better assist the ATCO in this aspect could be considered (as per White Paper WG85).
- In the longer term, the possibility for an airborne ‘What-if’ to be developed, with airborne ‘what-if’ information being available to the ground prior to RTA engagement, could be investigated.

The ability to 'Retain CTA' in the aircraft systems (rather than cancelling it altogether if/when a short-term tactical intervention is being carried out) has been shown to increase flexibility for the ATCOs conducting CTA Ops and this is appreciated by them.

- Further investigation could focus on how new support tools could assist the ATCO in best knowing when they can, or cannot, use such a function, thereby increasing the potential use of CTA. This investigation could also assess whether/how different ATC techniques used during tactical interventions might affect AU CTA benefits, and to what extent.

While accepting that higher predictability and higher accuracy of time keeping is usually an advantage, no direct assessment of the time accuracy actually needed for CTA operations has really been conducted, although some project validations (EXE-477) have indicated that different CTA time-keeping accuracies at different CTA locations, might be viable, depending on the traffic levels.

- Future investigation could look at what accuracy (and granularity) is actually needed when the CTA fix is located at various distances from the runway and in various traffic configurations (MED/MED and HIGH/HIGH). This investigation could also focus on the benefit/cost to the AUs if ground is using different accuracies.

While CTA has been assessed as being potentially feasible in MED/MED, how it could then be progressed to HIGH/HIGH operations is still an open question, and the assumptions and assessments made for MED/MED all need to be re-assessed for HIGH/HIGH operations.

Airborne FMS systems have been designed mainly with the airborne operation in mind, and much of the functionality that is available in the aircraft today is not intended for ATM purposes. One area of concern for ATC in CTA operations is the wide dispersion of airborne speed (and altitude) when aircraft are self-managing and controlling to a CTA time. Some of this dispersion can be narrowed by having the CTA fix located so as to coincide with when/where the aircraft's speed is adjusted to be in compliance with airspace speed constraints. Some of this dispersion could also be narrowed by having the aircraft operating to suitably stringent 'operational windows' that could be designed into a STAR.

- Future investigation could focus on how the FMS systems could be developed/enhanced to accommodate various types of 'operational windows' that might be considered by ATC to be desirable on the STARs.

Possible development in other related areas:

Even though the Extended AMAN concept is seen as mature and has been chosen for early deployment there are some aspects of E-AMAN operations, related to potential CTA operations within E-AMAN, which could still be considered as needing development/investigation.

- A CTA operation relies heavily on a stable AMAN sequence and operation, even at extended range. Sensitivity for changes to the E-AMAN sequences operating at these long ranges probably still needs to be investigated (with a view towards it being decreased) and the overall robustness of the E-AMAN sequence to disturbance (for whatever reason) probably also needs to be further developed.
- When considering sequence changes on a highly stable sequence an E-AMAN "what-if" function has been recognised as being potentially useful, and the provision of such a feature in the E-AMAN could also be an area of investigation in the future
- When operations such as CTA are not possible (e.g. due significant weather) or when high stability in the sequence at extended range is no longer required/needed, the possibility to alter E-AMAN operational and frozen horizons (from a determined time) and altering them online is desirable and could be an area for investigation.

Some E-AMAN operations and concepts presently being tested (e.g. XMAN) do not include CTA operations in their current testing/development. If such concepts come to fruition as they are currently tested then how CTA might be incorporated into them in the future would still need to be investigated.

Method Related Conclusion and Recommendation:

The Expert Group, as a multi-disciplined forum where aspects of concept validation work could be discussed, evaluated and influenced, was regarded positively throughout its lifetime, by the various members of the group itself, by the project, and also by other projects and by the SJU.

The project therefore recommends that such a representative group should be considered - and where suitable, established - in future validation activities.

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] P05.06.01 Latest Project baseline

[5] D06 EXE-05.06.01-VP-203 - Interim report, 29/02/2012

[6] D62 EXE-05.06.01-VP204 and 203 - Final report, 07/02/2013

[7] D64 EXE-05.06.01-VP-205 - Validation Report, 29/02/2012

[8] D66 EXE-05.06.01-VP-207 - Validation Report, 11/07/2012

[9] D71 EXE-05.06.01-VP-278 - Validation Report, 19/12/2012

[10] D80 EXE-05.06.01-VP-326 - Validation Report, 11/07/2013

[11] D101 EXE-05.06.01-VP-477 - Validation Report, 28/04/2016

[12] D82 EXE-05.06.01-VP-478 - Validation Report, 30/06/2014

[13] D103 EXE-05.06.01-VP-776 - Validation Report, 04/04/2015

[14] D84 P05.06.01 Deliverable - Step 1 - fully validated SPR, 30/11/2016

[15] D85 P05.06.01 Deliverable - Step 1 - fully validated INTEROP, 30/11/2016

[16] CASSIS - CTA/ATC SyStem Integration Studies, Flight Trials Report, 2009

[17] ERAT - Environmentally Responsible Air Transport, Final Report, 2012

[18] B.01-D83-Integrated_Roadmap_DS15_Release_Note

[19] D01 P05.06.01 Final Project Close Out Report, 12/08/2016

[20] D100 EXE-05.06.01-VP477 Validation Plan, 22/11/2013

[21] D63 EXE-05.06.01-VP-205 - Validation Plan, 30/09/2011

[22] D102 EXE-05.06.01-VP-776 Validation Plan, 11/08/2014

[23] D58 P05.06.01 Deliverable - Step 1 OSED - Iteration 1, 03/10/2011

[24] D67 P05.06.01 Deliverable Step 1 OSED - Iteration 2, 28/09/2012

[25] D70 EXE-05.06.01-VP-278 Validation Plan, 18/07/2012

[26] D81 EXE-05.06.01-VP-478 - Validation Plan, 22/11/2013

[27] D61 EXE-05.06.01-VP-204 - Validation Plan, 30/03/2012

[28] D79 EXE-05.06.01-VP-326 - Validation Plan, 13/12/2012

[29] D59 EXE-05.06.01-VP-203 - Validation Plan, 31/10/2011

[30] D65 EXE-05.06.01-VP-207 - Validation Plan, 21/12/2011

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