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Initial 4D Trajectory Management Concept Evaluation

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***Abstract*—Results are presented from the evaluation of Initial 4D (I4D) Trajectory Management concept developed under the Single European Sky ATM Research (SESAR) framework as a key feature associated with the first step towards the SESAR target concept named "Time-Based Operations". The objective of this first step is to synchronize trajectory information between Air Traffic Control (ATC) (Controllers and their supporting automation) and Aircrafts (Flight Crews and their supporting aircraft avionics) so that the arrival sequence can be optimized. The shared common view of the trajectory is translated into an agreed 3D route and a time constraint. The implementation of the I4D concept is distributed over aircraft avionics systems and ATM automation systems across navigation and communication domains. The I4D first flight trial was performed on 10 February 2012 following a series of activities in simulator to assess the concept and prepare all actors for the flight. The Airbus A320 Test Aircraft took off from Toulouse-Blagnac airport (France) to Stockholm Arlanda (Sweden) and tested all I4D key elements over six flight legs. The avionics modifications included an advanced Flight Management System (FMS), a onboard digital communication unit and the cockpit displays; ATM automation systems supported Ground-Ground coordination among the relevant Air Navigation Service Providers (ANSPs) and integrated down-linked aircraft trajectory information. Avionics interoperability was tested through the use of two independently developed FMS. The technical and operational feasibility of the concept was demonstrated from both the crew and the controllers standpoints. In addition, key performance requirements such as tolerance on the mutually agreed time constraint were met with a significant margin on all legs where it was applied. The analysis of the validation exercise led to the publication of a series of recommendations for the improvement of the concept and the evolution of the systems, identifying further investigations to be performed in flight test or simulation and highlighting short-term actions to be taken in datalink communication and navigation standardization groups.**

Keywords-trajectory-based operations, datalink, RTA, flight management system, air traffic management automation, flight test

I. INTRODUCTION

Within the Single European Sky (SES) ATM modernization program[1], the target operational concept is rolled out in three phases whereby time-based operations progress to trajectory-based operations to achieve performance-based operations.

4D Trajectory Management is a key feature of the SESAR program (the technology pillar of the SES ATM modernization program) supporting all 3 phases with improvements to both the aircraft avionics and the ATM automation systems, as well as procedures, human factors, standardization and regulation. Initial 4D operations are the first step of evolution from current systems (referred collectively as the deployment baseline) towards the full 4D concept of operations. The main objective is to achieve synchronization among stakeholders such that time prioritization for arrivals at airport is initiated, datalink is promoted to support the use of airborne trajectories in the ground systems and Controlled Time of Arrival (CTA) is used to sequence the arriving traffic and manage the queues.

At international level, the development of ATM solutions or upgrades to existing equipage is developed within ICAO's "Aviation System Block Upgrades" (ASBUs) with solution sets, transition plan and enablers to global interoperability described in the Global Air Navigation Plan[2]. To develop the ASBUs, ICAO made use of material provided by ongoing regional initiatives such as SESAR in Europe and NextGen in the United States and the supporting joint standardization groups (RTCA SC-227/Eurocae WG-85 for navigation standards in updated DO-236C, and RTCA SC-214/Eurocae WG-78 for data communication safety and performance standard). Having a mapping between the SESAR operational achievements and the elements in the ASBUs is key to support global interoperability. The Initial 4D concept is consistent with the Aviation System Block Upgrade number 1 (ASBU1).

Similarly, the SESAR Concept of Operations for the time-based operations step[3] can be seen as a European-tailored application of the ICAO Global Air Traffic Management Operational Concept[4].

Within the SESAR 4D Trajectory Management concept, Initial 4D constitutes a first step towards the full 4D target concept which is anticipated to already bring significant benefits to airspace users and at ATM network level. I4D concept was developed since SESAR phase 1 inception to culminate in 2012 with the demonstration of operational and technical feasibility with air-ground validations using pre-industrial systems and flight tests. This paper focuses on the results and recommendations from the flight test, focusing primarily on the onboard systems.

The I4D concept is first explained in terms of operational objectives, sequence of main events and key implementation elements within both aircraft avionics systems and ATM automation systems. The preparatory actions taken prior to launching the flight trial are then detailed. The second part of the paper focuses on the flight trial itself. Its objectives and the setup are first illustrated, followed by a description of the main results in view of the key performance items assigned to I4D operations. The main findings of complementary flight trials using revenue flights without the implementation of additional tools are included to highlight the limitations of current avionics and ground tools. Finally, all results from validation exercises, whether in simulator or in flight test, are presented, highlighting their impact on standards, whether existing or under development. The next steps include additional simulations and flight trials planned until the end of 2015. Pointers to what these tests will cover conclude this paper.

II. Initial 4D Concept

A. Overview

The objective is to optimize the arrival traffic at an airport through the synchronization of the airborne and ground trajectories around a common unique reference designated by a 2D point or Metering Fix (MF) and a time constraint, thus improving the reliability and accuracy of the arrival sequence.

When the aircraft is about 200Nm / 40 minutes from its destination airport, ATC initiates a trajectory negotiation process, whereby a 4D trajectory is negotiated via datalink between the ATC and the aircraft. First the 3D route is agreed between including Standard Terminal Arrival Route (STAR) and approach procedures applicable to the metering fix where the CTA will be placed.

Once this route is agreed, the aircraft navigation system is able to compute a reliable and achievable Estimated Time of Arrival (ETA) window defined by a min and max time values which is sent to the ground systems. The arrival manager (AMAN) then computes a CTA within that window trying to ensure that I4D flights are kept as stable as possible and proposes it to the ATC which after coordination between involved sectors sends it to the aircraft.

The final agreed 4D trajectory consists, therefore, in a lateral route with altitude/speed constraints and a single time constraint to meet with a required precision over a waypoint of the trajectory. On the ground, the AMAN function optimizes its arrival sequence thanks to the CTA allocation.

The research was performed within Single European Sky ATM Research (SESAR) work-package 9 “aircraft”, project 9.01 Airborne Initial 4D Trajectory Management.

Once the negotiation process is completed, the flight crew agrees to fly the negotiated trajectory within required performance and the ATC agrees to facilitate the negotiated trajectory, subject to separation provision.

During the execution of the agreed 4D trajectory, conformance is monitored by both the flight crew and the ATC. The 4D trajectory prediction is continuously computed onboard the aircraft and downlinked to the ground as needed. When no vertical clearance is issued, conformance will be performed in 2D. If a deviation is detected between the airborne and the ground trajectory, the responsible controller may be alerted by the ATM automation system, he will contact the aircraft by either voice or data to resolve the deviation.

Initial 4D operations may also prove of interest in managing en-route sectors capacity, complexity & demand balancing when the imposed time constraint is set a the transfer point between two sectors. Lastly, the concept may constitute a complementary method for managing crossing traffic if the time constraint is set at the crossing point; however, as the initial 4D concept supports a single time constraint, priorities in the needs will have to be assessed. These topics may be covered by further SESAR projects under the Full 4D framework.

B. Implementation

1) Airborne Segment

The implementation of the Initial 4D function onboard the aircraft is distributed among the following avionics systems:

- The cockpit display systems which ensures that relevant data related to the engagement and monitoring of the I4D operation onboard are displayed to the flight crew;
- The Flight Management System which ensure that the predictions computed onboard and the system performance in navigation and guidance are consistent with the I4D requirements;
- The communication system which role is to manage the Automatic Dependent Surveillance-Contract (ADS-C) and Controller-Pilot Data Link Communication (CPDLC) applications and ensure that datalink service is available and correctly managed with the ground.

All prototype equipments were installed onboard the Airbus A320 test aircraft referenced MSN1. This aircraft was equipped with a flight test installation allowing the capture of relevant information via

- Video recording of captain side Navigation Display (ND) and Primary Flight Display (PFD);
- Data recording (sent / received datalink messages, internal system traces, FMS inputs and outputs and FMS flight test buses).

2) Ground Segment

The implementation of the Initial 4D function on the ATM automation is distributed among the following ground systems:

- The arrival manager (AMAN) for the destination airport, which role is to build the arrival sequence so as to keep the I4D flights as stable as possible, is updated to provide the CTA and interact with the other ATC system for ground-ground coordination;
- The other ATC systems to support the distribution of the relevant AMAN CTA messages across systems and with the aircraft;
- The communication system which role is to manage the ADS-C and CPDLC applications and ensure that the trajectory information received from the aircraft (EPP) is dispatched to improve ground trajectory prediction (TP) tool and other ATC tools like queue management and conflict detection;
- The datalink service providers (ARINC/SITA), which network is used to exchange the information between the aircraft ATSU and the ground ATSU.

C. Preparation to the flight test

The flight test validation exercise is qualified on the Eurocontrol maturity scale named E-OCVM used throughout SESAR program as V3, indicating that the prototypes are in the last stage of validation before starting an industrial development phase. Prior to the flight test itself, the prototypes were integrated within a simulation bench representative of the real aircraft architecture and tests of air/ground interoperability were performed. Cockpit simulators coupled with ATC simulators were used to evaluate the usability of the functions by both pilots and controllers.

After these verifications, the systems were deemed ready for the operational validation and the flight trial activated. The preparation of the flight involved 9 rehearsal sessions with coupled simulators (Airbus single-aisle cockpit simulator, Noracon/NUAC and Maastricht/MUAC ATC positions simulators). These sessions aimed at solving some system limitations, tuning the scenarios and the interoperability aspects, and familiarize the flight test crew and dedicated controllers with the flight scenario.

Note that because the flight test crew was an integrand part of the design of the Initial 4D onboard function, they did not receive any particular training, nor was any training requirement considered as part of this validation exercise.

Note that Flight trials are only one tool among several supporting the operational validation of the I4D concept. The flight trial was a demonstration of the technical feasibility in real conditions. The core operational validation is based on coupled and non-coupled simulations made with MUAC and NORACON.

III. I4D Flight Test Results

A. Objectives

As explained in the preparatory steps, the Initial 4D concept was successfully evaluated in simulations. The focus of this section on results is on the flight trial evaluation. Compared to the avionics/ATM evaluations in coupled simulators, the objective of the flight trial for the onboard design was to confront it with real conditions and environment. These conditions translated in the use of operational systems both onboard and on the ground, the evaluation in real atmospheric conditions which impact the predictability of winds and temperature and insert exogenous disturbances in the process (e.g., turbulence, weather) and overall more representativeness of the Human Factors (e.g., crew pressure). The representativeness of future air traffic conditions was, however, of lesser extent.

The flight trial objective was to demonstrate the technical feasibility of the Initial 4D *nominal* operations and was not intended for validating operational benefits or feasibility.

The Initial 4D flight trial was performed on 10 February 2012, with an Airbus A320 test aircraft that flew from Toulouse to Stockholm, through French national airspace, MUAC and finally Danish-Swedish national airspace (NUAC). The flight was controlled by voice by operational controllers to ensure separation, while datalink was used to communicate between the aircraft and a dedicated controller position for all Initial 4D related operations.

B. Indicators

The indicators selected for the evaluation were based on the remarks made by the pilots and controllers during and after the flight, on engineering analysis of pilots and controllers actions/reactions and systems behavior both observed and recorded.

C. I4D First Flight Test Validation Scenario Execution

The validation scenario for this first flight test contained 6 different legs, each constituting its own self-standing validation test. A single time constraint – Controlled Time of Arrival – was issued per leg, i.e., 2 en-route CTA and 4 CTA in descent in the TMA.

Figure **1** to Figure 6 below show the flight profile and time constraint insertion for each of the leg.

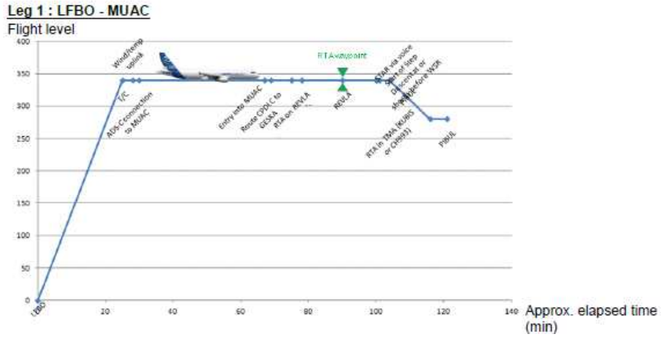

Figure 1: Flight Profile from Toulouse to MUAC

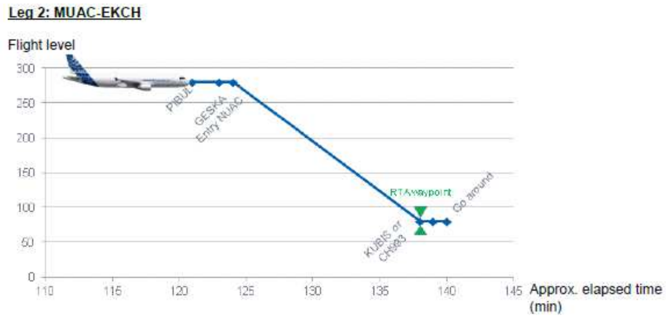

Figure 2: Flight Profile from MUAC to Copenhagen

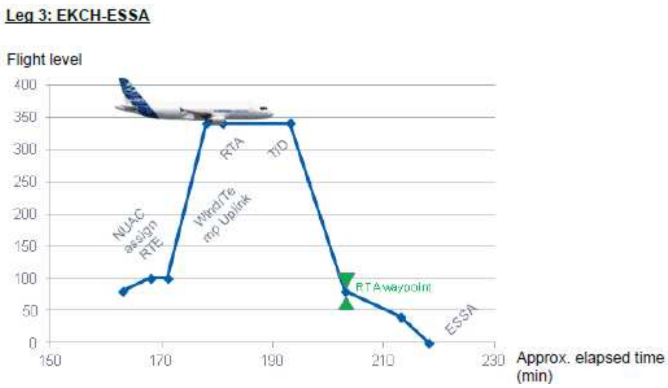

Figure 3: Flight Profile from Copenhagen to Stockholm

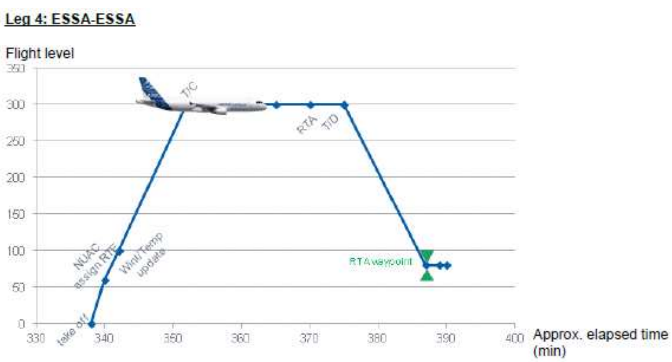

Figure 4: Flight Profile for the loop from/to Stockholm

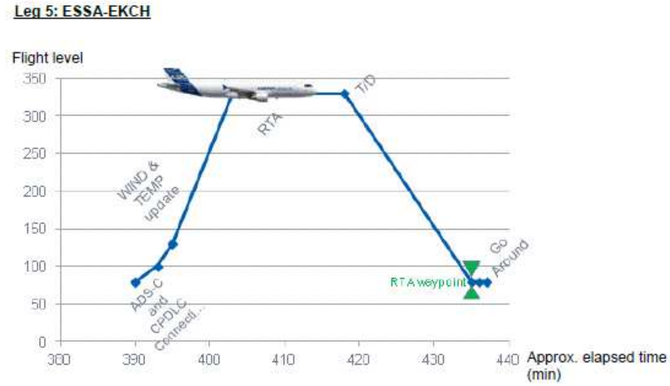

Figure 5: Flight Profile from Stockholm to Copenhagen

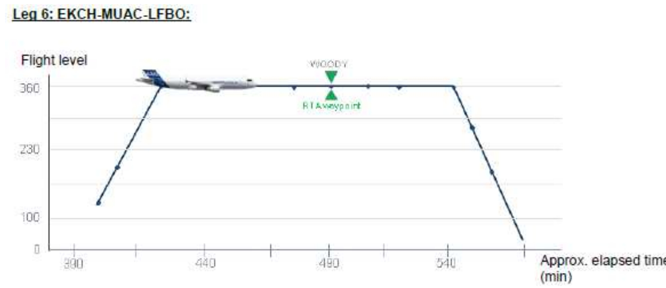

Figure 6: Flight Profile from Copenhagen to Toulouse

As part of the technical feasibility demonstration, avionics interoperability was assessed by using two independently developed FMS: Honeywell FMS on the first three legs and Thales/GE FMS on the last three legs as listed in TABLE I. below.

TABLE I. SUMMARY OF FLIGHT TEST SETUP

Leg	CTA definition			FMS provider
	ID	Metering fix	Type	
1	CTA1	REVLA	MUAC ENR	Honeywell
2	CTA2	KUBIS	EKCH TMA	Honeywell
3	CTA3	SA620	ESSA TMA	Honeywell
4	CTA4	SA489	ESSA TMA	Thales/GE
5	CTA5	CH446	EKCH TMA	Thales/GE
6	CTA6	WOODY	MUAC ENR	Thales/GE

D. Results

The results were organized to provide success/fail argument for each of the validation objectives, considering nominal operations in real conditions[5].

1) Feasibility of onboard nominal operations

In general, pilots were pleased that I4D task sharing was well aligned with the usual crew task sharing philosophy and that it was well balanced.

The pilots did not report any missing or out-of-sequence step or task in the onboard procedure, but they forgot once during the flight to insert the descent temperature profile. This omission could be traced to additional workload related to solving datalink instability issue which is not within the definition of “nominal conditions” and did not impact the achievement of Required Time of Arrival (RTA) performance objective on that leg.

The level of automation was deemed satisfactory by the pilots to the exception of the required manual entry of up-to-date temperature data in the FMS for the descent profile, which was thought of as useless and not desirable. Note that currently only temperature data for en-route waypoints benefit from an automated insertion through Airline Operations Center (AOC) datalink application, while wind data can be automatically inserted for both en-route and descent waypoints. This can be resolved by updating the AEEC A702A standard.

2) I4D onboard functions definition and performance

In general, no missing function was reported and the definition level of the prototyped function was deemed satisfactory. Equally, the pilots were satisfied with the I4D specific Human-Machine Interface (HMI) and its integration within the Single-Aisle family cockpit.

Two remarks were noted however regarding the time performance: there was an important deceleration when the RTA was set in the middle of the ETAmin/max window, and the initial ETA could be outside the ETAmin/max window.

The first observation can be easily explained using Figure 7. In fact, this scheme clearly shows that the FMS speed range when no RTA is defined - and corresponding to the pilot available range of cost index - is lower limited with regard to the aircraft flight envelope. To increase the RTA performance and to widen the range of delays that can be handled using RTA, the range of speed has been extended to the full aircraft flight envelope. In these conditions, for high cost index values - as it was the case during the flight trial - inserting a CTA can result in decelerations. This point was explained after the flight trial to both flight crews and controllers and it is now well understood. The main remark from controllers is that it is the lack of anticipation of large speed variations which is disturbing from their point of view. Two different recommendations have been emitted for next validation exercises. The first one is to have the AMAN favoring CTA values as close as possible to the aircraft initial ETA. The second recommendation is to define a simple algorithm that could be implemented on the ground side to roughly evaluate the initial speed adjustment at CTA insertion.

While the second ETA related observation may seem surprising to both pilots and controllers, it can be explained by the way the onboard system actually computes the initial ETA from a strict transcription of the FMS speed schedule over a given waypoint while the ETAmin/max window is computed from a speed range that includes head wind and tail wind margins. This phenomena, illustrated in Figure 7, is “per design” and is limited to cases where the initial aircraft speed is very high (or aircraft flying at high cost index).

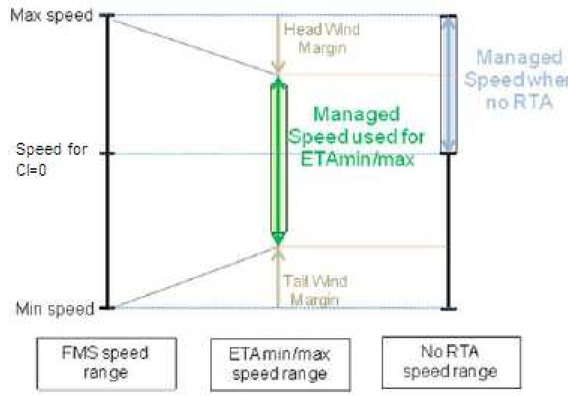

Figure 7: Speed Range and ETAmin/max Speed Range

Regarding the expected performance of the I4D functions, the navigation function performed satisfactorily with all 6 CTAs met within the prescribed tolerance despite sizeable discrepancies between the forecast and the measured wind/temperature data and unusual QNH as summarized in TABLE II. below.

TABLE II. SUMMARY OF CTA RESULTS

Leg/ CTA	Overfly time and error[a]			Deviation from nominal
	FMS log	**Crew log**	**ATC log[b]**	
1/CTA1	08:27:04 +4s	08:27:06 +6s	08:27:09 +9s	Sizeable errors in winds/temp data inserted accounting for time error
2/CTA2	08:59:59 -1s	09:00:02 +2s	09:00:02 +2s	
3/CTA3	09:56:15 0s	09:56:16 +1s	09:56:13 -2s	Descent temp no inserted. Unusual QNH (1043hPa)
4/CTA4	13:03:38 +2s	13:03:39 +3s	13:50:04 +1s	Unusual QNH (1043hPa)
5/CTA5	13:50:04 +1s	13:50:04 +1s	13:50:04 +1s	
6/CTA6	14:39:01 +1s	14:39:02 +2s	14:39:03 +3s	

a. Metering fix overfly times according to crew logs are always equal or greater than times according to FMS log, as crew is monitoring the waypoint sequencing through the navigation display or the MCDU RTA page reversion, thus including display and human reaction delays compared to the system log. Metering fix overfly times in the ATC log are either based on raw radar positions (NUAC data) or on the last EPP report received before the overfly (MUAC data); it is believed that differences from FMS log times come from the uncertainty in both data sources.

b. NUAC data for CTA2-5, MUAC data for CTA1 and CTA6.

The datalink function, however, experienced performance issues related to the difficulty to establish a stable ATN connection through VHF Data Link (VDL) mode 2. However, the analysis showed that this issue was independent from I4D airborne systems and a solution to this instability is available for the next flight trials.

A loss of VDL mode 2 coverage was observed 170Nm from Stockholm Arlanda, coherent with the theoretical coverage. Because the I4D implementation uses VDL mode 2, the limitations due to its coverage must be integrated when planning I4D operations.

Finally, the overall process time onboard the aircraft to send its trajectory information via the ADS-C Extended Projected Profile (EPP) dataset after the uplink of a route clearance may be quite lengthy; significant improvement is expected for the next flight test (e.g., reducing from 3 minutes to about 1) from the significant efforts made since February 2012 to address this issue; the computation time will be added to the EPP dataset, ETAmin/max to help gauge the downlinked data "age."

3) Appropriateness of chosen I4D CPDLC message set

Overall, the message set was judged complete and understandable by pilots for performing nominal I4D operations.

The main comment from the pilots is related to the loading aspect of the CTA clearance. While the CTA clearance message was loaded in the secondary flight plan, pilots recommended loading directly in the active flight plan for efficiency purposes and have a load in the secondary flight plan for preservation whenever possible. Indeed, in the current design, loading the CTA clearance consists in copying the active flight plan in the secondary flight plan while also adding to it the RTA on the designated waypoint. With a direct load into the active flight plan would save on the secondary flight plan verification and activation time, and leave that flight plan for other operational goals (e.g., what-if flight plan, next leg flight plan).

One undesirable effect was noted when using the uplink message number 267 *CLEARED [route clearance enhanced]*: the message – when loaded – erased all winds and temperatures data from the previous route, even for the identical route portions. This message is indeed interpreted by the FMS as a new flight plan, while controllers might be tempted to use it for route amendment. The proper use is being clarified at standardization level.

4) Technical feasibility of ground and air segments integration

Despite the technical issue that prevented a stable ATN connection during a portion of the flight trial, successful I4D operations could be repeatedly performed, including the demonstration of air/ground trajectory synchronization and CTA assignment using respectively ADS-C and CPDLC applications.

E. Regulatory and Standarization Impacts

While this single flight test did not highlight any result impacting regulation, some issues and comments have an impact on avionics standards.

The standards highlighted in [1] to support the I4D+CTA capability include:

- Safety and Performance Requirements (SPR) standard under development by the joint committees RTCA SC-214/Eurocae WG-78;
- ICAO doc 9880 "Manual on Detailed Technical Specifications for the Aeronautical Telecommunication Network (ATN) using ISO/OSI Standards and Protocols;
- Ongoing revision of the ICAO PANS-ATM (data communications);
- Ongoing revision of the Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation in ED75 by Eurocae working group 85 and in DO-236 by RTCA working group 227;
- Ongoing revision of ICAO Performance Based Navigation (PBN) manual.

While the above lists primary standards which will be impacted by the I4D related-demonstrations, other standards are likely to be identified from the results evaluations as illustrated in the following paragraph.

One of the recommendations was to extend to the descent the ability to load in the FMS the temperatures uplinked by ACARS/AOC. This can be achieved by an agreement to update the AEEC A702A standard for the AOC portion and an evolution of the FMS to comply with the amended standard.

Finally, the undesired effect of using uplink message 267 for a route amendment needs to be clarified in the ATS datalink Safety and Performance Requirements (SPR) standard under development by the joint committee RTCA SC-214/Eurocae WG-78.

F. Other recommendations

In terms of complementing the operational definition of nominal I4D operations, it is recommended that complete interconnection with all service providers be implemented at every ATC center participating in I4D operations to reduce ATN connection-related issues. Furthermore, the VDL mode 2 coverage should be taken into account when electing an ATC sector for I4D operations and ground datalink service providers should verify real datalink coverage to be conform with its theoretical value.

G. Complementary Flight Tests on CTA Operations

In addition to the first I4D flight trial, a validation exercise was conducted within the scope of the operational project addressing Queue Management[6] to evaluate on a wider scale and without added supporting tools how flight crews and ATC work with CTA operations. Note that in this case, the FMS RTA function is different from the I4D RTA function exercised during the I4D flight trial. These trials were performed with flights coming into Stockholm-Arlanda (ESSA), equipped with the FMS RTA functions and for which a CTA was set on a point during descent around FL100. Participating airlines included Scandinavian Airlines, Novair and Lufthansa; aircraft makes and models included Boeing 737-600, -700 and -800, Airbus A320 and A321.

The flight trials were performed in low to medium traffic densities where no major delays were imposed on the arriving traffic. The results were formulated in terms of recommendations, some of which will be resolved with improved ground and airborne technologies, while others are inherent to CTA operations and will require further investigation. In addition to the operational assessment of CTA operations, further analysis has been performed from an aircraft behavior perspective, in particular with respect to the effect of wind information quality on the RTA function, but was found to be inconclusive.

Quantitative and qualitative results from the flight trials showed that 92% of all flights managed to meet their assigned CTA within the tolerance set to ±30 seconds. Detailed recommendations can be found in [6], the main findings are recalled below:

- CTA operations as considered a positive method to absorb delays and sequence the arrival flow of aircraft is given situations;
- The airborne ETA function in the FMS performs well for CTA points between FL70 and FL202;
- The cross coordination between air traffic control centers for CTA operations is possible, but generates additional workload and requires additional time;
- The difference between the FMS-computed ETA and the ground-computed value at the metering fix and at the runway have been found to be large;
- In order to perform CTA operations in medium to high density traffic, more mature tools are needed on the ground;
- A long time interval is observed between the assignment of the inbound clearance and the reception of the FMS ETA;
- The ground systems require more trajectory information from the aircraft than currently available to reduce some of the uncertainty in CTA operations. If the uncertainty is not reduced in today’s environment, reduced capacity could eventually be seen with CTA operations;

The recommendations were issued after the operational flight trials:

- Datalink should be used as a tool to support further downlink of aircraft trajectory information and to aid in cross-centers coordination;
- The ground flight data processing system should be updated with the current aircraft trajectory information;
- The ground tools should be improved to efficiently address CTA operations;
- The turnaround time to obtain an ETA from the aircraft should be reduced.

Note that most of these recommendations found a first implementation in the Initial 4D flight trial.

H. Next Steps

Further air/ground coupled simulation validation exercises are planned with Maastricht and NORACON control centers to complete the coverage of Initial 4D validation scope. For example, validating the acceptability of I4D nominal operations (including workload aspects) will require a large panel of airspace user pilots; use-cases for abnormal operations need be performed to validate the preservation of a safe crew awareness level in nominal operations.

For each of the validation exercises, reports are published from an aircraft/onboard systems perspective as well as from the viewpoint of the control centers. As can be inferred from this paper, the views can differ.

The following validation exercises to be performed until 2015 will also address some of the recommendations from both [5] and [6], such as the undesirable effect on the crew of ETA outside the ETAmin/max window, and the monitoring of erroneous implementation of clearance message that occurred only once to see if there is more to it. In general, the next validation exercises will aim at consolidating the assessment of the operational maturity of I4D Trajectory Management.

IV. CONCLUSIONS

The first flight trial of the Initial 4D concept successfully demonstrated the operational and technical feasibility from both an airborne and an integrated air / ground perspectives.

All key concept elements were tested on each of the six flight legs. Avionics interoperability was shown through the use of two independently developed FMS prototypes. Datalink communications supported the objective to synchronize the trajectory between the air and the ground segments through the use of a prototype version of the new datalink standard over ATN, in particular a new application supporting the downlink of FMS computed reliable and achievable arrival time window and airborne trajectory. The integration of the airborne trajectory in the ATM automation systems was shown to improve the trajectory prediction and support the computation of an achievable Controlled Time of Arrival. The operations are likely to become more reliable with a more stringent tolerance on meeting the CTA constraint down to 10 seconds; this navigation performance was met by the aircraft within the prescribed tolerance on all six legs.

The stakeholders favorably assessed the concept in terms of procedures, expected tasks, Human-Machine Interface design and workload. Despite the limited evaluation, sufficient feedback was collected to plan for the next validation activities, including additional flight tests, extend or affirm statistically some conclusions in simulator and propose modifications to existing standards.

ACKNOWLEDGMENT

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REFERENCES

[1] SESAR JU, European ATM Master Plan, October 2012.

[2] ICAO, doc 9750, Global Air Navigation Plan.

[3] SESAR JU, SESAR Concept of Operations Step 1, April 2012.

[4] ICAO, doc 9854, Global ATM Concept.

[5] SESAR JU, WP09.01-D21, Validation Report of the I4D first flight to support Release 1-issue02, June 2012.

[6] SESAR JU, WP05.6.1-D64, Exercise-205 – Wide Scale Flight Trials – Validation Report, edition 1.1, February 2012.

AUTHOR BIOGRAPHY

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From 2008 to 2011, Dr. Mutuel oversaw Thales Avionics contribution to SESAR for the navigation and communication domains during the program definition and the launch of the first system projects, including Airborne Initial 4D Trajectory Management.

She is an AIAA senior member, and a past recipient of Amelia Earhart fellowship and an active contributor to several RTCA and AEEC standardization groups.