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Single European Sky Implementation support through Validation

Sixth Framework Programme

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The focus of the EP3 WP6 activity is the technical validation of Airborne and Ground Enablers linked to ATM Capability Level 2. Its objective is to reach a TRL4 for the tested functions. It corresponds to an early validation process that enables to refine the system specification of the function, to demonstrate that the function is feasible and measure function performances.

The evaluation done in WP6 concentrated on ATM service level 2 (ready to be deployed in 2013).

Two concept elements were studied in more details using an integrated air-ground industry based platform:

- Initial 4D Trajectory Management

  The main objective was to assess the Initial 4D functionality relevance in regards to the ATM concept of operations. Secondary objective was to verify operational acceptance from a flight crew perspective and identify potential issues related to the function design.

- ASAS Sequencing & Merging

  The 3 following manoeuvres were evaluated: Remain behind, Merge behind, and Radar vector then merge behind

In addition, an RTA performance evaluation ran several batches of scenarios to collect statistical results on RTA precision achieved by the FMS. The successive batches were run varying key parameters, such as wind data.

Results of the study gave a good confidence in the capability of the airborne system to comply with the RTA performance requirement.

Another aim was to confirm the batch tool as a mean to measure FMS performance. The study shows that this kind of tool is adapted to get statistical results, but also to highlight and analyse implementation problems. Some potential improvements were identified to have better environment models (simulation of the airbrake extension in the pilot model, simulation of the wind and temperature in the meteo model).

This document details the evaluations that have been performed and the associated results both on airborne and ground side.

1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This document provides the consolidated validation exercise report for all validation exercises performed in Episode 3 WP 6 “Technological Enablers”. This document is the delivery D6.5-01 Consolidated Validation Report for EP3 WP6.5 “Results’ Analysis and Report” which will contribute to the elaboration of the Integrated Report of EP3 WP2.5.

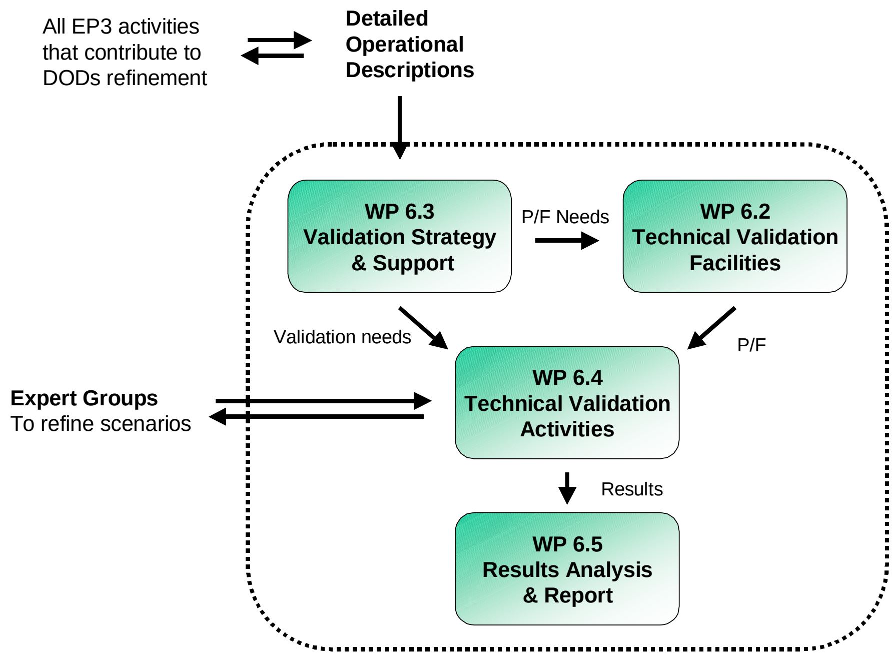

Table 1-1 Elaboration of EP3 integrated Report

The evaluation done in WP6 concentrated on ATM service level 2 (ready for initial deployment in 2013 – i.e. revenue flight trials and specific sites in trials operations).

Two concept elements were studied in more details:

- Initial 4D Trajectory Management;
- ASAS (ASPA) Sequencing & Merging.

These concept elements were investigated further in terms of RTA performance, Initial 4D trajectory exchanges and further work on ASAS (ASPA) Sequencing and Merging.

“Initial 4D” is based on the use of:

- A 4D trajectory exchanged and synchronized between air and ground;
- The use of CTO with a precision of 30s (at 95%) in En-Route and 10s (at 95%) in terminal area.

“Initial 4D” functions are used for planning and sequencing ATM activities but not for separation.

ASAS Spacing is considered to be the first step of ASAS, the 2013 target necessary step before ASAS Separation (2020).

- Three manoeuvres (Remain behind, Merge then Remain, Vector then Merge) are defined;
- The acquisition and maintaining of spacing in end of En-Route, descent and approach is performed with a precision of 5s;
- There is no delegation of separation responsibility to the A/C;

1.2 INTENDED AUDIENCE

The intended audience includes EP3 WP and exercise leaders, SESAR JU, the European Commission and SESAR WP Leaders;

This document is intended for use in EP3 WP2.5 “Reporting and Dissemination” as input for the consolidated project Reporting and Dissemination document.

1.3 DOCUMENT STRUCTURE

The document is structured as follows:

- Section 2 introduces the methodologies, techniques and tools used for validation;
- Section 3 summarises the results obtained against the maturity of technological enablers;
- Section 4 lists the references and applicable documents.*
- Detailed validation exercise report for all validation exercises performed in Episode 3 WP 6 are provided in appendix

2 TOOLS, TECHNIQUES AND METHODOLOGIES FOR VALIDATION

2.1 INTRODUCTION

Technical validation is defined as a set of activities leading to the:

- Demonstration of Industrial Feasibility:
  - Demonstration that we would be ready to launch an industrial development and that any technical blocking point has been detected and solved;
  - Supports technical derisking;
  - Includes work on airborne and ground architectures supporting the envisaged operations;
  - Includes cockpit integration.
- Assessment of technology choices;
- Assessment / trade off between required and possible performances:
  - Includes accuracy, availability and integrity of data;
  - Response time…
- Interoperability (as defined in EUROCAE documents):
  - Data exchanged, Protocols used…

The focus of the EP3 WP6 activity is the technical validation of Airborne and Ground Enablers linked to ATM Capability Level 2 (Initial 4D and ASAS Sequencing & Merging). Its objective is to reach a TRL4 for the tested functions. It corresponds to an early validation process that enables to refine the system specification of the function, to demonstrate that the function is feasible and measure function performances.

2.2 APPROACH

Industrial maturity assessment is based on the TRL (Technology Readiness Level) concept based on NASA initial definitions, which can be applied to technologies, functions, architectures, or methods & tools.

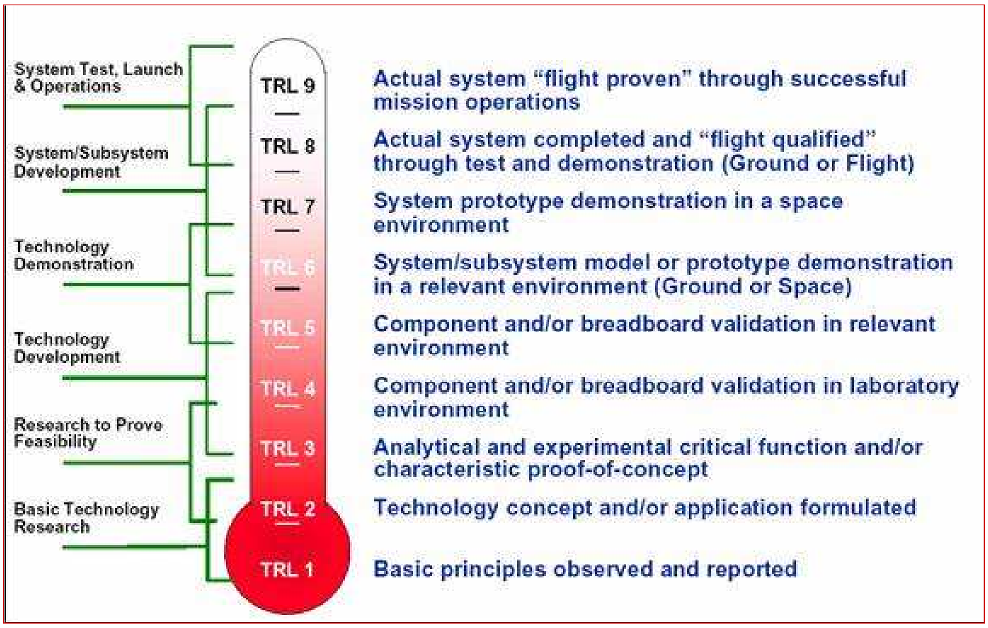

Figure 2-1 – NASA TRL scale

The TRL scale can be roughly linked to E-OCVM concept maturity levels as presented below.

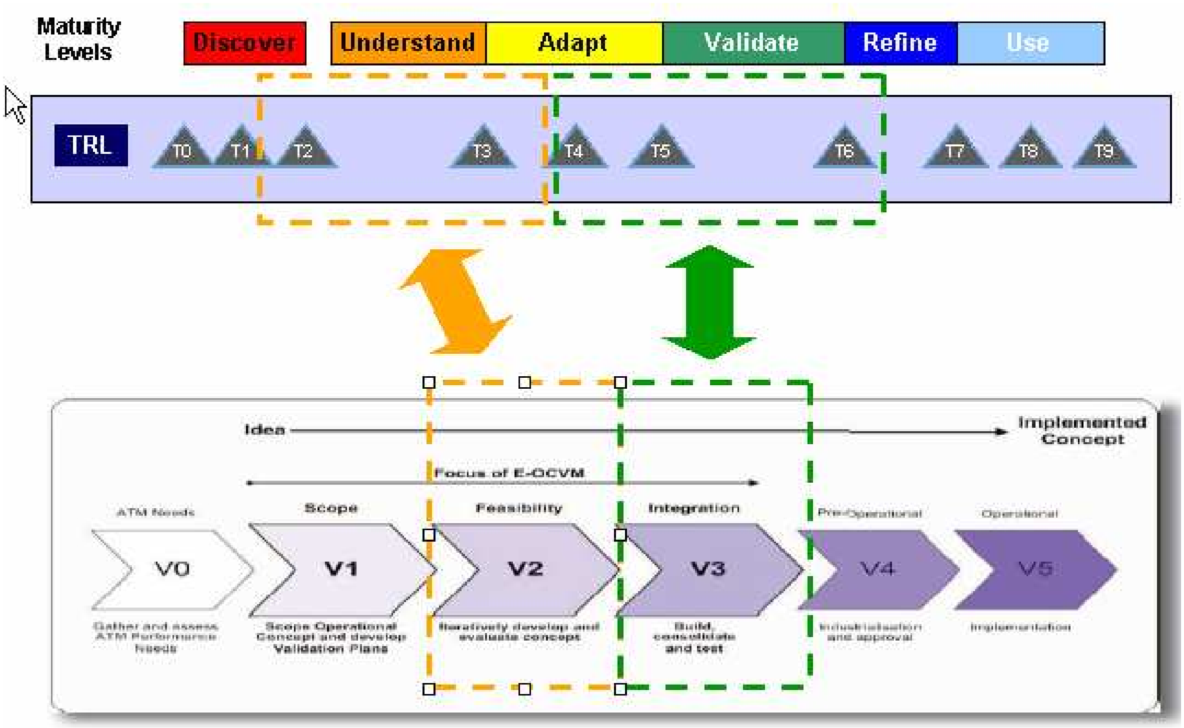

Figure 2-2 – Rough correspondence between TRL and E-OCVM scales

2.3 Validation Methodology

2.3.1 Airborne evaluations

Five to six runs are planned for each session with either Airbus experimental pilots or Airbus training pilots.

The global duration of an evaluation run is around 4 hours.

- Before entering the cockpit simulator, the flight crews follow a 1-hour training
    - So as to understand the global environment in which they are going to operate, the kind of operations they might be requested and the reasons of these operations.
    - The specific HMI and functional cockpit elements for the application are described so as to have flight crews able to operate any S&M manoeuvre they might be asked by the controllers during the scenarios
    - The limitations of the simulator are described during the briefing too
    - The global objectives of the evaluation session were mentioned to the participants.
    - The behaviour rules for evaluators and observers are reminded so as to avoid influencing on feedbacks obtained during these runs: silent observation during flight scenarios, no comment whatever the mistakes, misunderstanding, etc. ; no answer to questions asked by the flight crew unless a blocking point prevents from keeping on flying the scenario. Flight crews were invited to formulate their comments, thought, doubts and questions so that notes can be taken during the scenarios.
- After the training the flight crew enters the cockpit and flies the proposed scenarios during about 1h30 (about 1/4h was needed between scenarios for simulator re-initialisation).
- Once all the scenarios were run, a debriefing of about 1h to 1h30 is taking place in order to go through all the questionnaire elements and the events observed during the scenario runs.

Each evaluation run is performed and evaluated with at least four persons:

- Two pilots
- One or two interviewers
- One or more observers

Pilots evaluate the function. They bring their experience and expertise to assess operational, functional and HMI aspects.

Interviewers ask questions on the subjects of evaluation, problems observed during scenario runs, comments made, ask for development of arguments, consolidation of operational needs. They lead the evaluation.

Observer(s): They report pilot's comments as close as possible of his/her opinions in order to pick up operational arguments. They might help the interviewers to complement feedbacks collection.

Between to scenarios runs, a short debriefing takes place so as to collect first feedbacks. Then a 1h to 1h30-long debriefing was conducted in a meeting room to gather feedbacks from the pilots. A questionnaire prepared in advance by designers and human factors specialists was used to explore and evaluate the different aspects of the ASAS S&M function.

All data collected through the test and the debriefing were analysed. Moreover, recorded parameters were used to assess the performance of the algorithm.

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These data were used to produce recommendations to improve the design of the on board implementation of the ASAS Spacing S&M application.

2.3.2 ATC evaluations

The principle of the evaluation is to run an operational scenario on the air / ground platform simulating an operational environment, depicted on the following figure:

The following methodology is followed to collect the feedback of the ATCO's and operational experts:

- Reminding the operations principles in order to share a common view between participants;
- Presenting the scenario;
- Presenting the air / ground system configuration supporting the scenario run;
- Running the scenario with the ATC controllers and operational experts, and recording any significant or unplanned event that impacted the progress of the scenario;
- Debriefing with the ATC controllers and experts.

The following figure describes the setup used for the evaluations.

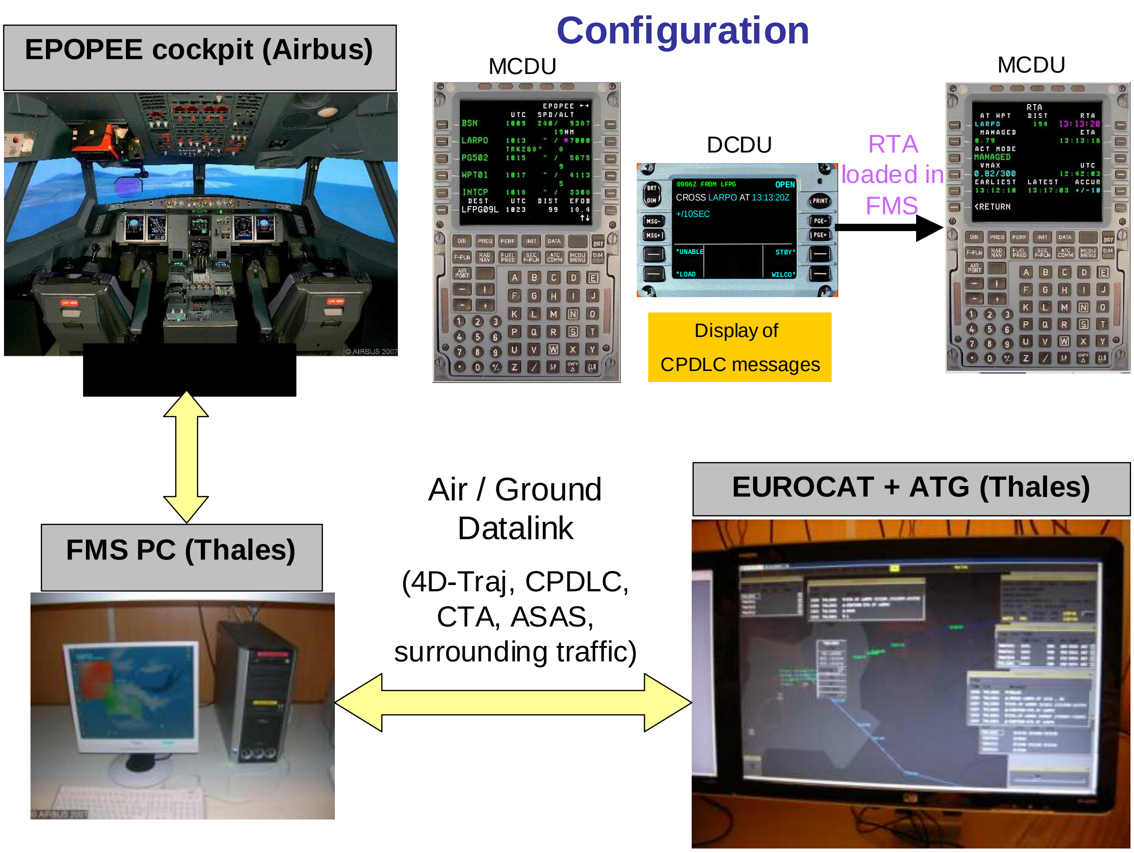

Figure 2-3 – Platform setup used for evaluations

The overall duration of the evaluation session is around 3 hours including the presentation, the scenario run and the debriefing.

A briefing on the operational background of the Initial-4D and ASAS S&M operations was given to the interviewed ATC controllers and operational experts.

A presentation of the air / ground simulation platform is given, followed by a focus on the ATC System (Thales EUROCAT) and the Air Traffic Simulator (Thales ATG-X) interfaces. In particular, Thales Air Systems representatives described the new or modified functions that had been implemented to support the new procedures.

Air Traffic Controllers and ATC operational experts participate to the evaluation. They bring their experience and expertise to assess operational, and HMI aspects. After the presentation of the air/ground configuration, they focused their attention on the ATC system (EUROCAT) and the Air Traffic Generator (ATG-X). By staying close to the EUROCAT CWP and ATG-X screen, they were able to follow the detailed interactions done on the EUROCAT CWP and the ATG-X screen. Thales and Airbus technical experts performed the interactions.

An observer takes note of the comments made by the participants during the run.

A debriefing is conducted to gather the feedback form the participants.

The discussion takes place around the comments related to each step of the scenario.

In addition, a questionnaire prepared before the session, is distributed to the Air Traffic Controllers and operational experts, and filled in after the meeting, due to time constraints.

3 MATURITY OF TECHNOLOGICAL ENABLERS

3.1 INTRODUCTION

The focus of the EP3 WP6 activity is the technical validation of Airborne and Ground Enablers linked to ATM Capability Level 2. Its objective is to reach a TRL4 for the tested functions. It corresponds to an early validation process that enables to refine the system specification of the function, to demonstrate that the function is feasible and measure function performances.

The WP6 validation platform evolutions follow a typical industrial development, adapted to allow quick loop development and validation:

- High-level specifications for the evolutions derived from operational needs identified by Episode 3 operational work packages (WP5.3.6, TMA Expert Group WP5.3.1) and Standardization Working groups (Initial 4D, ASAS S&M RFG);

- Specifications and validations of the sub-system evolution (simulated FMS, simulated ATSU, ground system).

Then two kinds of evaluations are carried out:

1. Technical evaluations focussing on the validation of performances of the technical solutions, which can use validation platform without human in the loop (use of AIRLAB, use of batch tool),
2. Technical validation evaluating the operability of the HMI and operator situation awareness from pilot and controller point of view, which uses EPOPEE. These sessions are typically organized in 3 steps: Briefing, evaluation run, debriefing.

3.2 APPROACH

The main guideline for technical validation is to focus on the assessment of the acceptability and usability of the proposed initial 4D and ASAS S&M concepts and functions as described in the preceding paragraphs.

- The WP6 approach is to set-up an environment that is realistic enough to allow consistent situation awareness for both pilots and air traffic controllers, while nevertheless taking into account industrial constraints, including business case aspects. By nature, this will limit the scope of possible validation area within WP6, but allows a high quality progressive build-up process.
- The WP6 is investigating the use of integrated air-ground platforms to perform industrial feasibility assessment. The WP6 technical validation is focusing on air and ground ATM capabilities to be deployed by 2013-2015. It will therefore enhance maturity of those capabilities and pave the way to SESAR projects by using the platform and techniques (Airbus Cockpit Simulator - EPOPEE, Thales simulated FMS and EUROCAT ATC system).
- By using state-of-the-art industrial components, the WP6 approach allows to demonstrate that advanced concepts as investigated in more experimental contexts (e.g. Gate2Gate, Mediterranean Free Flight, TMA2010+, etc.) for which identified requirements can be assessed without having to suffer from some simplified modelling techniques. Its validation results are therefore 'making the bridge' that could introduce further industrialisation phases as described by the TRL process.

- As presented in EPISODE 3 WP 6 deliverable “Requirements for technical validation” (Ref. [2]), the validation strategy of the other Episode 3 work packages will be more focusing on the operational concepts validation:

  “…In many cases only parts of the OI-steps will be validated, e.g. regarding AO-0301 Crosswind Reduced Separations for Departures and Arrivals all procedural aspects how reduced separations could be achieved and managed are not part of the approach. Instead, the exercise assumes that reduced separations can be achieved, and it validates the impact with regard to the possible capacity increase. The same is valid for most of the other OI-steps as the validation exercises focus on concept clarification and expanding the repertoire of cost-effective validation techniques”.

WP6 has therefore a complementary approach, providing a sound basis for the hypothesis used in the elaboration of the operational concepts validation scenarios.

3.3 Initial 4D

3.3.1 Description of the function

“Initial 4D” is based on the use of:

- A 4D trajectory exchanged and synchronized between air and ground;
- The use of CTO with a precision of 30s (at 95%) in en route and 10s (at 95%) in terminal area.

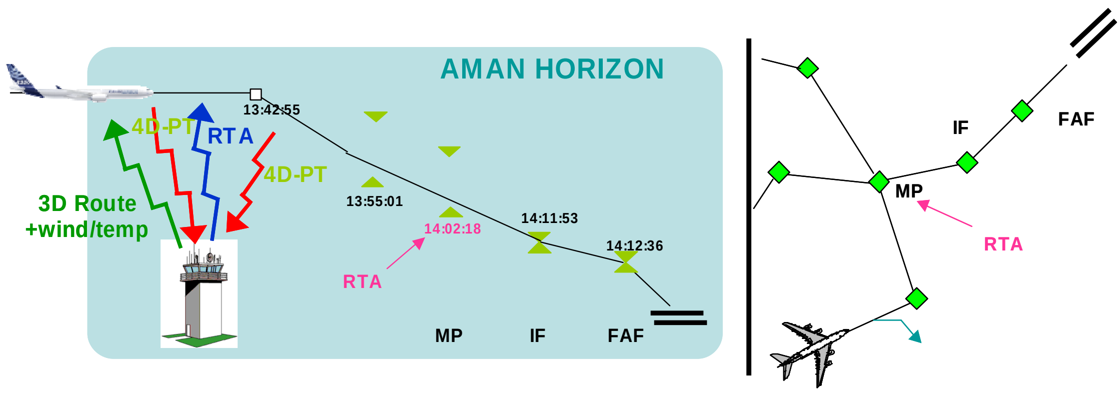

Figure 3-1 – Initial 4D Operations

“Initial 4D” functions are used for planning and sequencing ATM activities but not for separation.

Air-Ground trajectory synchronization is transparent.

Datalink exchanges are handled as per FANS function:

- Exchanges between flight crew and ATC via DCDU;
- Flight plan and RTA can be loaded from DCDU to FMS SEC FPLN.

When set by the flight crew, RTA is managed by the FMS.

Accurate ETA calculation requires MET data to be uploaded into the FMS.

The associated key elements of such concept are:

- CTA – time constraint on a defined merging point associated to an arrival runway:

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- Airborne: being able to reach a given point at a requested time (provided about XX nm before);
- Ground: have the capability to deal with the agreed constraint (for consistency with the rest of the traffic).

- Precision Trajectory Clearances (PTC-2D), and Trajectory Control by Ground Based Speed Adjustment:
  - PTC-2D: Envisaged to be of high importance during transition period, while a large amount of the traffic will still remain non FMS/4D and data-link equipped, although the RBT concept of operation should also be applicable to them;
  - Ground Based Speed Adjustment: to be discussed with SESAR concept experts (this procedure seems to correspond to "open-loop" instruction).
- Uplink of ATC constraints and downlink of 4D data:
  - ATC constraints;
  - Downlink of 4D data: current position, predicted positions (Altitude, Latitude, Longitude, Time Over significant Point, Point Type), and FMS status (managed, selected, etc.).

The expected benefits of Initial 4D can be summarized as follow:

- 1st results of benefits analysis performed with support of EUROCONTROL tend to show interesting potential benefits from airside perspective, assuming several feasibility road blocked are cleared through validation:
  - Reduction of fuel consumption and emissions through CDA enabled by Initial 4D;
  - Reduction of crew workload in descent and approach;
  - Reduction of delays in TMA and en-route.
- Initial 4D used to de-bunch traffic at TMA entry should also bring good benefits from ATC perspective:
  - Reduction of controller workload;
  - Predictability of traffic;
  - Enhanced coordination between ground actors;
  - Reduction of environmental impact.

3.3.2 Technical validation objectives

The targeted validation activities aimed at:

- Relevance of the Initial 4D function:
  - Variations of engine speed according to the different accuracy values and outside parameters (wind, temp);
  - Robustness of the RTA algorithm according to the outside parameters (wind, temp);
  - Understanding of the Initial 4D procedure;
  - Capacities to negotiate the RTA, follow the RTA instructions of ATC, and monitor the Initial 4D mode.

- Relevance of WIND/TEMP uplink information and mechanization (procedure via AOC);
- Appropriateness of RTA access mechanization and presentation;
- Relevance and appropriate understanding of ETA window;
- Appropriate understanding of missed/made status (RTA page, F-PLN, Navigation Display);
- Communications relative to the Initial 4D function:
  - Understanding of the ATC instructions (CPDLC / voice);
  - Integration of the task within the CPDLC clearances procedure (CLEARED TO …);
  - Appropriateness of CPDLC message phraseology of RTA instruction (“CROSS <> AT <>”).
- Assess the predicted trajectory "quality" of the current and future FMS (implementing the Initial 4D). Address the impact of wind information;
- Validate the choice of set of data, downlinked from A/C to the ground, and the way they are transmitted (event-based, cyclically…). Make sure that they are relevant;
- Assessing the improvement brought to the ground functions by the downlinked 4D-Trajectory.

3.3.3 Technical validation results

The main operational issues addressed during the evaluation campaign are related to:

- Global integration of Initial 4D function with other tasks performed by the crew and with the other functions available in the cockpit
- Aircrew 'task sharing in the context of the Initial 4D procedure
- Control Initial 4D usability and information usability regarding use of the MCDU, with ATC

It is based on synchronization of trajectory between air and ground occurring in a transparent way.

The datalink functions were implemented as in FANS:

- The exchanges between flight crew and ATC were via the DCDU
- Flight plan and RTA could be loaded from DCDU to FMS second flight plan
- RTA was managed by the FMS.

It was important that frequent meteo updates were received to have accurate RTA.

Main results from the airside were:

- Easy to use, the function does not impose extra task load
- RTA was met with ±10s accuracy below FL100 in 95% of cases if RTA within ETAmin/max window
- Need to clearly know if, and when, RTA becomes unachievable
- PF / PNF Task sharing is not significantly modified

- Transparent ETAmin/max synchronization with ATC appreciated
- Route clearance loading well appreciated
- MET Data update through datalink is a must

The main feedback from ATC controllers were:

- The optimum location of the CTA-waypoint needs to be determined.
- More awareness needed on the behaviour of an A/C flying RTA
- The issue of "mixed" traffic need evaluation
- Initial 4D does reduce the number of tactical actions needed

Initial 4D Cockpit Feedback MET data update after a route clearance

- The majority of the crews took too much time or even forgot updating the MET data
- Pilots have no added value in manually loading these data
- ATC does not know if the MET data in the FMS are up-to-date
- Risk that the ATC proposes an unacceptable RTA (longer RTA negotiation)

Initial 4D Cockpit Feedback RTA Management

RTA met with ±10s accuracy below FL100 in 95% of cases if RTA within ETA_{min} / ETA_{max} window

Loading the RTA for verification … "It is not intuitive to load before validating the RTA"

Speed changes due to RTA algorithm

- Speed changes may be surprising for the flight crew
- The pilot needs to understand the behaviour of the aircraft
- No specific indication that the aircraft is under RTA management

Monitoring the compliance to the RTA

- The monitoring of the RTA constraint on ND and MCDU may not be possible because it could be out of the display or the display might be cluttered
- Need to clearly know if and when RTA becomes unachievable

Initial 4D ATC Systems Preliminary Feedback Improvement of the Ground TP

Impact of using the downlinked airborne 4D trajectory on the Approach trajectory predicted by the Ground TP was analysed in two situations:

Situation	Predicted Level vs. time	Predicted distance-to- destination vs. time	Predicted ETO vs. time
First reception of the down-linked airborne data	Predicted descent profile significantly improved	Error reduced to less than 5 NM	Error reduced to less than 20s

	Predicted descent path within 500 ft of actual path		
Application of a CTA by the FMS and reception of updated down-linked data	Update correctly taken into account by Ground TP	Update correctly taken into account	Update correctly taken into account

Initial 4D Preliminary ATCO Feedback

ATCO Main comments are:

- What is the optimum location of the CTA-waypoint?
- ATC Coordination: which sector should decide of the CTA value (and location?) for a given flight? Which sector should transmit the CTA to the aircraft?
- More awareness is needed by the ATCO on the behaviour of the aircraft flying a CTA procedure
- How far can a "mixed" traffic (e.g. A/C's flying CTA procedures mixed with A/C flying conventional procedures, A/C's with heterogeneous performance, etc) share the same route?
- The number of flights simulated by the WP6 evaluation scenarios should be increased to better assess the impact of the Initial-4D on the ATCO tasks
- Demos have shown that Initial 4D reduces the number of tactical actions needed

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3.4 ASAS Sequencing & Merging

3.4.1 Description of the function

ASAS Spacing is considered to be the first step of ASAS, the 2013 target necessary step before ASAS Separation (2020).

- Three manoeuvres (Remain behind, Merge then Remain, Vector then Merge) are defined;
- The acquisition and maintaining of spacing in end of en route, descent and approach is performed with a precision of 5s;
- There is no delegation of separation responsibility to the A/C;
- Airborne: capability to fly the ASAS spacing procedures in managed mode;
- Ground: capability to initiate an ASAS S&M instruction, and to monitor its execution.

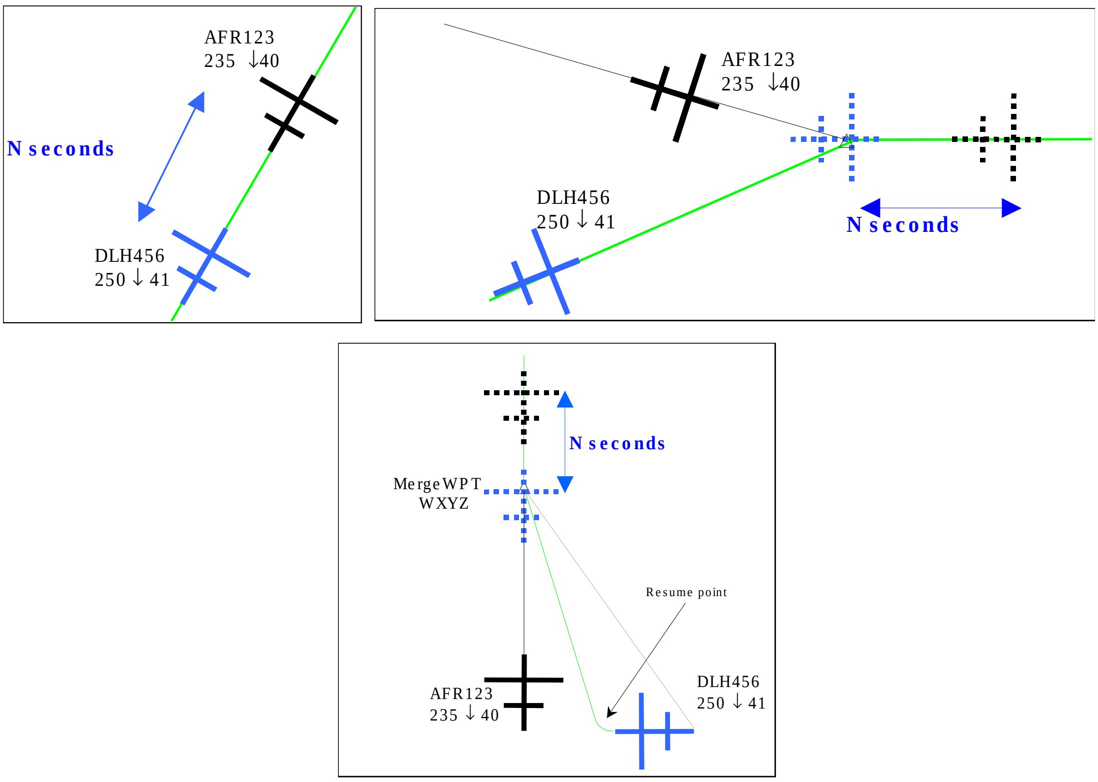

Figure 3-2 – ASAS S&M Manoeuvres: Remain behind, Merge then Remain, Vector then Merge

Its principle is based on:

- The controller delegates a manoeuvre to the flight crew:
    - o The controller requests the flight crew to identify the target A/C.

    Example of phraseology: "AIRBUS 001, select target CSN 781 and advise relative position".

    - o Spacing instruction from the controller ➔ the flight crew establishes and maintains a TIME SPACING between its A/C and another A/C.

    Example of phraseology: "AIRBUS 001, remain 90 seconds behind target".

- The controller remains responsible of SEPARATION between A/C.

The ASAS sequencing & merging expected benefits are summarized as follows:

- Capacity / Regularity due to less radar vectoring;
- Combined with CDA, it may reduce fuel consumption and emissions;
- Complementary to 4D at big airports;
- Probably more beneficial at secondary airports;
- Robustness of the procedures.

With a Target frame for operations:

- Spacing application for pioneers in the 2013 timeframe;
- Applications in Approach and Oceanic environments;
- Automated solution with limited impact: Software only, using ATSAW baseline.

3.4.2 Technical validation objectives

The targeted validation activities will aim at:

- Appropriateness to perform the ASAS sequencing & merging manoeuvre (before the engagement and during the manoeuvre);
- Acceptability of the prerequisites of the ASAS sequencing & merging function;
- Relevance of the use of datalink instead of voice (workflow, type of message, parameters to load…);
- Understanding and appropriateness of the ownship behaviour;
- Relevance, consistency (with the phraseology), understanding and completeness of the information provided;
- Test the ASAS sequencing & merging function in degraded cases:
  - Impossibility to engage (one or more pre-requisite missing or algorithm detecting the impossibility to perform the requested manoeuvre);
  - Impossibility to acquire the instructed spacing;
  - Impossibility to maintain the instructed spacing.

3.4.3 Technical validation results

The main conclusions were:

- The functions were easy to use, they do not bring extra task load to the crew
- Easy navigation through MCDU traffic pages
- Relevant and readable spacing information on Navigation Display
- Global behaviour of the aircraft during acquisition and maintaining of the spacing is satisfactory (dynamics of the algorithm seem acceptable)

Some elements required further investigation:

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- Make the ASPA S&M function robust to any unwanted disconnection of A/P (auto-pilot) or A/THR (auto-thrust).
- Cockpit task sharing between PF and PNF to be studied

ASAS sequencing & merging Cockpit Feedback Task sharing

Pilot (Flying / Non Flying) tasks sharing was not fully clear and can depend on flight phases

- Assigning a target can be assimilated to a guidance order à PF action
- Assigning a target can be assimilated to a "DIR TO" à PNF action
- Assigning a target requires the display and monitoring of the surrounding traffic (ATSAW function). Therefore it could be considered as a surveillance task.

Proposition:

- PNF in charge of communication with ATC
- PNF selects target aircraft according to ATC request
- PNF confirms target identification to the ATC (voice or datalink)
- PNF selects manoeuvre and parameters according to ATC request
- PF cross-checks before engagement and engages the ASAS sequencing & merging manoeuvre

ASAS sequencing & merging Cockpit Feedback Phraseology

Phraseology to be used onboard was not fully clear. Pilot did not know:

- •**How to announce** "**MISSED**" during maintaining or "**UNABLE**" to acquire.
- •If they should announce it or not.

Pilots are in favour of the use of datalink.

- Reduces frequency occupation in high-density area where ATC contact can be difficult by voice.
- Reduces misunderstanding and error risks (target identification, manoeuvres types and parameters).
- Allows taking advantage of A/C systems integration i.e. load datalink messages directly in the system.

ASAS sequencing & merging ATCO Feedback

Main conclusions summarized below:

- There should be pre-requisites for initiating an ASAS sequencing & merging manoeuvre in order to be able to perform efficient and safe relative spacing. For instance, speed range compatibility, navigation performances, wind (especially when the following aircraft deviates from more than 90° from the target aircraft course).

- Should the ATC system include tools that would, before actually issuing the instruction, predict the trajectory ("dogleg") that will be followed by the instructed aircraft in a Heading then Merge maneuver, in order for the controller to make it sure that it is achievable safely?

- When using CPDLC for providing the ASAS sequencing & merging instruction to the flight crew, is it better to send the whole instruction in a single message, or in 2 subsequent messages? May be more convenient for the pilot to be sent in a single message, but it might help the pilot if a prior notice was given beforehand (to get him prepared before the manoeuvre in order to be able to check quicker if it is feasible)

- Heading then Merge manoeuvre appears to need a buffer space around the “dogleg” which would increase with the altitude. This adds complexity for managing the separation with other aircraft in the sector. The complexity for the control could even increase if the manoeuvre was leading the aircraft to cross a sector that should not be concerned by the flight. This buffer space size would increase with the altitude: this does not contribute to an increase of the air space capacity. Structured routes and specific corresponding procedures could be necessary for the dogleg section.

- The way the ASAS manoeuvre has to be monitored in the ATC is still to be investigated especially during the dogleg section of the heading then merge manoeuvre: should the ASAS manoeuvre be permanently monitored by ATC tools or would it be sufficient to get alerts only in case of predicted conflicts? For the Heading then Merge manoeuvre the additional point (location, computed by the FMS should be downlinked in the 4D trajectory, displayable on the controller working position and possibly used by conflict detection tools such as TCT.

- The simulations showed that hazards and safety cases would have to be assessed. For instance, situations such as the aircraft head of the ASAS train having a behaviour that becomes no more compatible with the followers.

- MUACC today works with flights at approach handover with distance spacing of about 10 NM and close to 5 NM in dense traffic situations. Therefore, time spacing given in ASAS sequencing & merging instructions should be always selected to values less than 150 sec.

3.5 TRANSITION FROM 4D TO ASAS

3.5.1 Technical validation objectives

The scenarios consisted in a nominal transition between Initial 4D and ASAS sequencing & merging. This case represents what is foreseen as an operational use: Pre-sequencing of aircraft using Initial 4D at the end of cruise, and then, in the TMA area, use of ASAS sequencing & merging to maintain the sequence thus easing the management of the different aircraft flows.

The main objectives of the session were:

- To confirm that proposed datalink messages are properly understood by flight crews,

- To evaluate the global use of datalink for ASAS sequencing & merging exchanges (in particular with the LOAD function capability),

- To evaluate the global usability of “Heading then merge” manoeuvre during nominal operations,

- To confirm on board implementation choices,

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- To assess the need of cockpit integration coherency between complementary functions like Initial 4D and ASAS sequencing & merging, and point out incompatibilities and similarities.
- To get a feedback from an ATC viewpoint on the acceptability and feasibility of the proposed new operational procedures regarding the transition from Initial 4D to ASAS sequencing and merging;
- To collect comments on the ground ATC system (THALES AIR SYSTEMS EUROCAT) ability to support the operations (e.g. HMI);
- To identify and discuss ways of improvements.

3.5.2 Technical validation results

3.5.2.1 General

The main feedback from pilots and ATC controllers were:

- Initiation of the ASAS S&M procedure does not necessitate that both involved aircraft have the same altitude profile: only an identical lateral route is necessary.
- The later the ASAS sequencing and merging procedure is triggered, the shorter are the available times for the controller and aircrew to achieve their tasks, the larger is the risk of overload for one or both of them and possibly the unfeasibility of the manoeuvre. Whatever the selected procedure, the times needed by the controllers to prepare and send the instructions and by the aircrew to trigger the manoeuvre must be optimized as much as possible. This is even more critical for the Heading then Merge manoeuvre when a course deviation is to be performed first for achieving the time spacing on the merge point. If the planning controller prepares the ASAS instruction and the executive controller just has to validate it and instruct the pilot, this will limit the load of the executive controller and may optimize the time taken in the ground for issuing the ASAS instruction to the aircrew.
- Further significant investigations are needed about feasibility in a large scale of ASAS-based procedures and conventional procedures in a same environment while there is still a small proportion of ASAS capable aircraft.
- For the Merge and Remain behind manoeuvre, when both routes of the aircraft are converging with a small angle, the time spacing should not be guaranteed only from the merge point but also before it in order to also respect the separation in the route segment preceding the merge point.
- The integration of instruction parameters into the aircraft systems thanks to the LOAD command proposed was considered as necessary so as to avoid entry errors and ease the evaluation of the feasibility or not of a given manoeuvre by the flight crew.
- There was no difficulty to understand the transition (reference change) between the 4D RTA and the ASAS sequencing & merging instruction. Even if aircraft speed management for 4D is based on a fix reference whereas ASAS sequencing & merging function is based on a moving reference, it is agreed that it is transparent for the crew.

3.5.2.2 Recommendations on the simulation means

Weather conditions

The WP6 experiments have highlighted the need to implement the simulation and processing of weather conditions (wind, temperature) impacting the planned and actual aircraft trajectories, in the airborne and ground systems, as presented below:

Aircraft Simulation performing manoeuvres

The aircraft model should include the simulation of winds (mean wind, gust winds) and varying temperatures (mean temperature or possibly gradients), under which the aircraft is actually flying.

Air Traffic Generator (ATG)

The Air Traffic Generator should be able to simulate surrounding aircraft encountering winds (mean wind, gust winds) and varying temperatures (mean temperature or possibly gradients). The ATG should offer the capability to simulate different weather conditions for each aircraft of the generated air traffic.

The simulation of gust winds will enable to assess the robustness of the aircraft guidance system when encountering unexpected and variable winds (capability of the aircraft to tackle erratic winds and to revert to the planned trajectory)

Flight Management System (FMS)

The Flight Management System should be able to implement and take into account a model of the weather conditions (winds, temperatures) under which the airborne system is planned to fly along its predicted trajectory.

The weather model (and its subsequent updates) will be uplinked to the FMS by a meteo organisation known and recognised by the ANSPs.

Ground System (EUROCAT-E)

The ATC ground system should be able to refine the prediction of the trajectories of the aircraft to be controlled by taking into account a model of the weather conditions (winds, temperatures) under which the aircraft are planned to fly.

The weather model (and its subsequent updates) will be provided to the ground system a meteo organisation.

Consistency of the weather models

In order to improve the system simulation consistency, the different weather simulations should be derived from a common model.

Simulated air traffic

The WP6 experiments have highlighted the need to refine the simulated surrounding air traffic behaviour by giving the aircraft models the capability to fly CTA procedures or ASAS S&M procedures.

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3.6 EXPERIMENT RESULTS AND SYNTHESIS

Id	Question	Source	Objective	Exercise	Result
1	What are the performance requirements of the airborne FMS RTA function? (Link to FMS accuracy enabler R&D work)	SESAR	Measurement of 2D trajectory performance in terms of integrity, accuracy and stability and of single CTA compliance.	6.4.1	The CTA performance study gives excellent trends on the capability of the avionics system to respect a CTA with the required accuracy. Cases where the requirement was not met have been explained and corrective implementation solutions have been identified
2	What is FMS capability to stick to RTA constraint after tactical clearance?	WP6	Not addressed by WP6: In the scenarios, the aircraft is flying in full managed mode.		
3	What is the minimum time horizon for RTA negotiation?	WP6	Measurement of the ETA_{min} / ETA_{max} window size as a function of the time to go the RTA waypoint.	6.4.1	The measurement of the [ETA_{min}, ETA_{max}] window size shows that the time authority decreases rapidly after the top of descent. Therefore, it is recommended to negotiate the CTA during the cruise phase
4	What is the most efficient way to adjust the speed schedule or cost index of the aircraft to meet the RTA?	SESAR	Assess CTA compliance and accuracy through FMS Speed control.	6.4.1	The algorithm implemented in the FMS is using speed control. Therefore the results of the CTA performance study proves the validity of this solution
5	Besides the FMS, what kind of other automation tools (autopilot, VNAV descent modes, auto-thrust) is required in the aircraft to comply with RTA? How should this automation operate?	SESAR	Demonstrate, at the technology level, that the RTA with 10s accuracy in descent can be achieved in full managed mode (lateral, vertical and speed), thus with auto-pilot and auto-thrust.	6.4.1	The batch tool simulates full-managed mode. So the results of the study are valid for this mode of flight

Id	Question	Source	Objective	Exercise	Result
6	What is the required time tolerance of the FMS RTA function at the RTA constraint and at each distance before the RTA constraint? What should be the strategy of the FMS to achieve the RTA?	SESAR	Assess ability to meet CTA compliance within a time window appropriate to support a Ground given arrival slot.	6.4.2	This objective has been achieved by means of scenarios addressed in Appendix B.
7	How to maintain controller situation awareness for an aircraft with a CTA	WP6	Assess CWP HMI capability of presenting necessary information to monitor Aircraft flying an RTA.	6.4.2	This objective has been achieved by means of scenarios addressed in Appendix B. Comments pertaining to the way of improving the EUROCAT CWP HMI have been captured and discussed
8	Which level of CTA monitoring conformance should be available? When an alarm is raised, who is acting?	WP6	Assess detection and signalling of CTA non-conformance both on the air and groundside.	6.4.2	Detection of CTA non –conformance was implemented in the airside, not in the ground side. When the aircrew was warned by the FMS that the CTA could not be maintained anymore, this was transmitted to the controller by voice.
9	What is the required granularity of forecasted winds to meet the RTA with the required tolerance?	SESAR	Impact of meteo on FMS predictions.	6.4.1	The algorithm implemented in the FMS is robust to wind and temperature error. It ensures a good success of CTA compliance if the CTA is specified within the ETA_{min} / ETA_{max} window.
10	Is there a relation of this time tolerance with the operating context (En-Route, TMA) and/or the phase of flight (cruise, descent, approach)?	SESAR	Assess RTA performance for different RTA waypoints (before T/D, in descent, above or below FL 100).	6.4.1	The study has been performed only for a RTA waypoint in descent below FL 100, which is the more stringent situation for the FMS. Indeed, in the descent phase, the aircraft shall be guided on the descent profile while in cruise phase the altitude is stabilized. Furthermore, below the FL100, the speed limit is an additional constraint.

Id	Question	Source	Objective	Exercise	Result
11	Definition of the format and content of air-ground data link messages required to support the exchange of CTA constraints.	SESAR	Assess the ability to negotiate a CTA constraint via datalink between air and ground.	6.4.2	This objective has been achieved by means of scenarios addressed in Appendix D. Comments pertaining to the way of improving the EUROCAT CWP HMI have been captured and discussed
12	How do trajectory prediction tools use improved aircraft RNP capability to improve Medium Term Conflict Detection (MTCD) accuracy and reduce uncertainty?	SESAR	Check the validity of the method and strategy selected by the Ground ATC automation system to take into account the airborne trajectories. Check the capability of the Ground Trajectory Predictor to generate and provide 4D-predicted trajectories in a smooth and timely manner, to the other ground functions that need them (e.g. Controller Working Position, MTCD). Assess impacts on the interactions between the Ground Trajectory Predictor function and the other ground-based functions.	6.4.2	This objective has been achieved by means of scenarios addressed Appendix D. Comments pertaining to the way of improving the EUROCAT CWP HMI have been captured and discussed The MTCD function was present and activated in the EUROCAT system and indirectly beneficiated of the better accuracy of the Ground Trajectory Prediction for the EPOPEE aircraft, but the impact of the use of the enhancement of the Trajectory Prediction on the MTCD was not widely experimented. It would have necessitated running many scenarios with a tuning of the MTCD alert parameter to provide statistics on the true or false alerts raised.

Id	Question	Source	Objective	Exercise	Result
13	Which data needs to be downlinked? When and how often does the data need to be downlinked? In which format does the data need to be downlinked?	SESAR	Demonstrate, at the technology level, that the Ground ATC automation system will be capable to efficiently take into account the trajectory data downlinked by the airborne system. Define the technical characteristics of this process (downlink, fusion with ground trajectory).	6.4.2	This objective has been achieved by means of scenarios addressed in Appendix B.
14	What level of tools and automation is required on the cockpit to set up, complete and execute the ASAS manoeuvre?	SESAR	Assess the ability to provide efficient tools to the pilot to execute an ASAS Sequencing and Merging manoeuvre. Measurement of performance of ASAS spacing procedure in term of integrity, accuracy and stability.	6.4.3	Please refer to the "AIRBORNE" section in Appendix C.
15	What will be the communications, navigations and surveillance requirements between ATC and the target and delegated aircraft to set up, execute and complete the ASAS manoeuvre?	SESAR	Assess the ability to initiate an ASAS Sequencing and merging manoeuvre via datalink.	6.4.3	This objective has been achieved by means of scenario #4 addressed in Appendix C.
16	What level of surveillance is required? Do existing applications of CPDLC, ADS-C and ADS-B support this?	SESAR	Not addressed by WP6.		

Id	Question	Source	Objective	Exercise	Result
17	How to maintain controller situation awareness during an ASAS sequencing and merging manoeuvre?	WP6	Assess CWP HMI capability of presenting necessary information to monitor Aircraft during an ASAS manoeuvre.	6.4.3	This objective has been achieved by means of scenario #4 addressed in Appendix C. Comments pertaining to the way of improving the EUROCAT CWP HMI have been captured and discussed (refer to Appendix C)
18	In an ASAS manoeuvre what are the instructions that have to be transmitted by voice or by datalink?	WP6	ASAS experiments are using both voice and datalink. Capture pilots and controllers preference for media addressed by 6.4.3.	6.4.3	This objective has been achieved by means of scenario #4 addressed in Appendix C and scenario #5 addressed in appendix D. In order to avoid duplication, the Controllers preferences that have been captured are reported in Appendix C.
19	What are the downlinked data necessary for the controller to monitor an ASAS manoeuvre?	WP6	Define the data to be downlinked during an ASAS manoeuvre and check that it is sufficient for the controller to monitor the ASAS manoeuvre.	6.4.3	EP3 has tacked this objective, and comments / issues have been raised. This will have to be further investigated in the SESAR projects pertaining to ASAS S&M.
20	Evaluation of the merits of relative (ASAS) or absolute (RTA) Time Based Separation (TBS) techniques; in terms of runway throughput. Both techniques appear to have merits under different circumstances. Are there local issues that influence the answer? Associated is the issue on evaluation of feasibility and safety of less than 50 second spacing on final approach, especially if this involves late clearance to land.	SESAR	To study the transition aspects between Initial 4D and ASAS (RTA on a waypoint and then ASAS instruction after this waypoint).	6.4.4	The transition issues have been identified (Refer to Appendix D)

Id	Question	Source	Objective	Exercise	Result
21	Does the underlying communications method (i.e. VDL2, 1090MHz ES, satellite) provide sufficient capability (bandwidth, speed, etc), or are new communications links required?	SESAR	Not addressed by WP6.		
22	What navigation performance is required by the target and delegated aircraft?	SESAR	Not addressed by WP6.		

4 REFERENCES AND APPLICABLE DOCUMENTS

4.1 References

[1] Episode 3 Overall description of the platform and its capabilities
E3-WP6-D6.2-01, v2.00, 12-Aug-2009

[2] Episode 3 Requirements for technical validation
E3-WP6-D6.3-01, v1.00, 21-Sept-2009

4.2 Applicable documents

[3] Episode 3 **DOW** Description of Work – Annex 1 to the Episode 3 contract V3.1 July 2009

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