# EPISODE 3

## Single European Sky Implementation support through Validation

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# DOCUMENT CONTROL

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# EXECUTIVE SUMMARY

Episode 3 is in charge of the initial validation of the operational concept as expressed by SESAR Task 2.2. The initial emphasis is to perform a system level assessment of the concept's ability to deliver the defined performance benefits in the 2020 timeframe.

Episode 3 Work package 6 supports this system level assessment by validating air and ground functions linked to concept elements, whose Initial Operating Capability dates are around 2013-2015, and delivering initial performance and industrial feasibility elements paving the way towards the target concept.

In order to be efficient and focus on SESAR core elements, evaluations performed in Episode 3 Work package 6, were limited to Initial 4D and ASAS sequencing & merging air and ground functions.

This document describes the scenarios to be used during technical validation activities.

# 1 INTRODUCTION

## 1.1 PURPOSE OF THE DOCUMENT

This document shall provide an overall description of the operational scenarios to be used during technical validation activities performed in Episode 3 WP6 - Technological enablers.

As described in EP3 DOW [13], technical validation activities have been scheduled in two steps:

- An initial step called "Initial scope" focuses on the Initial 4D concept and the two Airborne Separation Assurance System Sequencing & Merging (ASAS S&M) manoeuvres that are neither requiring FMS modifications, nor the THALES AIR SYSTEMS air traffic simulator use ("Remain behind" and "Merge then remain behind");

- The final step called "Extended scope" further refines the Initial 4D concept, extends ASAS S&M to all three manoeuvres defined in the Requirements Focus Group RFG ASPA OSED 30 ("Remain behind", "Merge then remain behind" and "Vector then merge behind") and then transition from CTA constraint to ASAS S&M operation and the impacts on the procedures and systems.

- The current version of this document includes the scenarios needed to carry out the "Initial scope" validation and the "Extended scope" validation, is an official deliverables to the European Commission and will be made public after official approval

The scenarios used for these technical validation scenarios make use of today's route and airspace structure, rather than the user preferred trajectory environment which is the objective of SESAR for 2020. As the impact assessment is focused at the detailed technological aspects of the system, the choice of a structured route environment does not limit the relevance of the results to the 2013/15 timeframe.

## 1.2 INTENDED AUDIENCE

This document is to be used:

- As a communication material to the community, including the Episode 3 consortium, SESAR JU and the European Commission;

- As a reference for technical validation teams to ensure that major elements of validation scenarios are properly shared and agreed.

Note: This document does not replace the detailed scenarios, briefings and questionnaires to be used during the evaluations, which remain internal to AIRBUS.

## 1.3 DOCUMENT STRUCTURE

Sections 2 and 3 describe the scenarios used for validation of Initial 4D (linked to EP3 WP 6.4.2 - Air Ground Initial 4D Management).

Sections 4 and 5 describe the scenarios used for validation of ASAS S&M (linked to EP3 WP 6.4.3 - Spacing Performance Validation).

Section 6 describes the scenarios used for validating the transition from CTA constraint to ASAS S&M operation (linked to EP3 WP 6.4.4 – transition from CTA constraint to ASAS S&M operation).

Section 7 describes the scenarios used for assessment of CTA performances in the airborne system (linked to EP3 WP 6.4.1 – 4D Airborne Navigation Capability for CTA / RNP).

The Appendix 1 gives more details about flight plans and environment used in the scenarios.

## 1.4 GLOSSARY OF TERMS

| Term | Definition |
|---|---|
| 3D | Three Dimensional (LAT, LONG, ALT) |
| 4D | Four Dimensional (LAT, LONG, ALT, TIME) |
| A/C | Aircraft |
| ADS | Automatic Dependent Surveillance |
| ADS-B | Automatic Dependent Surveillance - Broadcast |
| ADS-C | Automatic Dependent Surveillance - Contract |
| AIS | Aeronautical Information System |
| AOC | Airline Operational Communication |
| ASAS | Airborne Separation Assurance System |
| ASPA | ASAS Spacing |
| ATC | Air Traffic Control |
| ATM | Air Traffic Management |
| ATSU | Air Traffic Service Unit |
| CPDLC | Controller/Pilot Data Link Communication |
| CTA | Controlled Time of Arrival |
| DCDU | Data Communication Display Unit |
| EIS | Electronic Instrument System |
| E-OCVM | European Operational Concept Validation Methodology |
| EP3 | Episode 3 |
| EPOPEE | Airbus Cockpit Simulator |
| ETA | Estimated Time of Arrival |
| $ETA_{max}$ | Latest achievable ETA over a waypoint |
| $ETA_{min}$ | Earliest achievable ETA over a waypoint |
| EUROCAT | THALES AIR SYSTEMS product for civilian Air Traffic Control Centres |
| FAF | Final Approach Fix |
| FCU | Flight Control Unit |
| FDPS | Flight Data Processing |
| FG | Flight Guidance |
| FIR | Flight Information Region |
| FIR | Flight Information Region |

| Term | Definition |
|---|---|
| FL | Flight Level |
| FMS | Flight Management System |
| HMI | Human Machine Interface |
| ILS | Instrument Landing System |
| JU | Joint Understanding |
| MCDU | Multi-purpose Control and Display Unit |
| MRTS | Multi Radar Tracking System (EUROCAT) |
| MTCD | Medium Term Conflict Detection |
| ND | Navigation Display |
| ODS | Operator Display System |
| OSED | Operational Services and Environment Definition |
| PFD | Primary Flight Display |
| RFG | Requirements Focus Group |
| RNAV | Area Navigation |
| RNP | Required Navigation Performance |
| RTA | Required Time of Arrival |
| RWY | Runway |
| SESAR | Single European Sky ATM Research |
| S&M | Sequencing & Merging |
| STAR | Standard Arrival |
| TBD | To Be Defined |
| TC | Traffic Computer |
| TGMS | Trajectory Guidance Management System |
| THR | Threshold |
| TMA | Terminal Area |
| TP | Trajectory Predictions |
| TOD | Top Of Descent |
| TRL | Technology Readiness Level |
| TR6 | Thales Air Systems |
| UIR | Upper Information Region |
| WILCO | Will be Complied with |
| WP | Work Package |

**Table 1 - Glossary**

# 2 SCENARIO 1 – USING DOWNLINKED TRAJECTORY IN THE GROUND SYSTEM

## 2.1 OBJECTIVE

The primary objective of this scenario is to use aircraft downlinked trajectory in the ground system to improve the ground trajectory predictions, and as a consequence, to highlight the benefits on the ground functions that rely on the predicted trajectories [1], with a potential focus on the MTCD (if relevant) or other functions.

Other objectives are:

- Verify whether the elements of the 4D-trajectory that are downlinked, and the way they are downlinked (e.g. rate) meet the ground Trajectory Predictions needs;
- Identify the potential elements that should also be downlinked (if any) not only to meet the ground Trajectory Predictions needs, but also to be displayed on the Controller Working Position;
- List potential amendments that may be proposed to the standardisation groups dealing with ADS-C.

## 2.2 OVERALL DESCRIPTION

The aircraft downlinks its trajectory to the ground system, periodically and on change events. The ground system uses the downlinked trajectory to improve its trajectory prediction.

The aim is to compare the situations with and without the use of downlinked trajectory. The scenario highlights the visible effects for the controller.

Note: this scenario will not be run with pilots as no cockpit aspects are at stake.

## 2.3 DETAILED DESCRIPTION

The scenario uses the flight plan described in Appendix 1 (§ 0) and starts at takeoff.

EPOPEE aircraft sends its 4D trajectory to the ground system.

The flight initial trajectory is altered through:

- Changed actual weather (or meteorological) conditions from forecasted ones loaded & used by FMS
- Cost Index modification
- Speed change.

[1] It is expected that the following ground functions should benefit from the improvement of the ground TP predictions: Flight Data Processing (FDP), Coupling, Safety nets, Medium-Term Conflict Detection (MTCD), Air Traffic Situation Display.

The 4D trajectory sent to the ground system provides the complete list of points managed in the FMS from the current position to the runway threshold of the airport of destination. These points are not only the waypoints of the flight plan route but also intermediate points computed locally in the FMS. For each point the following information is provided:

- Position in latitude and longitude
- Level
- Estimated Time of Over-fly
- Point type (for some of these points, for instance 'Top of Climb' or 'Top of Descent')

Note that neither the RTA nor the $ETA_{min}$ and $ETA_{max}$ on the points are provided. The request for information on $ETA_{min}$ and $ETA_{max}$ are performed by the ground system in CPDLC (not in ADS-C).
The TTA is not provided with the 4D trajectory.

The ground system uses EPOPEE aircraft 4D trajectory to update its trajectory prediction. The look ahead of the ground system prediction is until the runway threshold and the aircraft 4D trajectory may be used to update it until this last point.

The controller requests the EUROCAT system to display the trajectory computed by the ground, the airborne downlinked trajectory (lateral and vertical views), and the table of estimates over LARPO[2].

The MTCD is in operation.

First step: The scenario runs without taking into account the downlinked trajectory in the ground system. The ground system does not receive 4D trajectory prediction from the aircraft yet.

Expected observations:

- Due to the ground Trajectory Predictor not taking into account the downlinked trajectory, there are discrepancies between the times over LARPO estimated by the ground and the aircraft systems and differences between the two vertical profiles. This is mainly due to the different models used by the aircraft and the ground systems (The Ground System uses the BADA and when available GRIB meteo data, it is not simulated in the run scenarios. The airborne FMS uses Aircraft performance models and Weather data for waypoints along the flight plan), the different data and unplanned events faced by the aircraft (e.g. unplanned winds)
- A conflict is detected by MTCD.
- Nevertheless, periodically, EUROCAT computes internal 4D automatic position reports from the tracks issued by conventional surveillance means (radar, etc.) and uses these reports to update its ground flight plan accordingly, thus progressively getting closer to the airborne predicted trajectory.
- This process therefore converges but much slower than if the ground Trajectory Predictor had received the aircraft trajectory.

[2] LARPO is a map navigation way point used as merge point

- The ATCo takes no specific additional action during the run of the scenario.

Second step: The scenario runs taking into account the downlinked trajectory in the ground system: The EUROCAT MTCD is tuned considering the trajectory accuracy improvement.

The MTCD function needs to be tuned in order to reach an acceptable trade-off between its two key performances:

- Percentage of nuisance alerts (i.e. ratio between the number of mistakenly detected future conflicts and the number of genuine conflicts), which should not be too high to maintain ATCo confidence in this function
- The reliability of the MTCD function (the genuine future conflicts should not be missed)

Increasing the accuracy of the predicted trajectories (which are the main inputs of this function) enables to "tune" the MTCD (mainly increase its sensitivity) which leads to improve the two above-mentioned performance parameters.

Expected observations:

- The estimates and vertical profile between ground trajectory and airborne trajectory are nearly the same;
- No conflict is detected by the MTCD;
- The estimates over LARPO are stable.

# 3 SCENARIO 2 – INITIAL 4D CONCEPT: NEGOTIATION AND EXECUTION

## 3.1 OBJECTIVE

The objective of this scenario is to show a first application of the Initial 4D concept based on the negotiation and the execution of a 3D trajectory + a single CTA.

The trajectory downlinked by the aircraft is a "4D-trajectory" in the sense that it each point is associated with a planned time. Nevertheless, during the air/ground negotiation, only one time constraint (CTA) is given to the aircraft by the ATC. The aircraft recomputes a 4D-Trajectory; including an ETA that tries to meet the CTA.

The exercise addresses technical validation and focuses on:

- Feasibility of a CTA negotiation between the air traffic controller and the flight crew, taking into account downlinked information (4D trajectory, [ETAmin, ETAmax]window) and using CPDLC messages;
- Capacity of the FMS to comply with a CTA with an accuracy of 10s, including robustness to meteo forecast errors.

This scenario is linked to OS-33: "Negotiating a proposed ATC revision to the RBT due to queue management".

## 3.2 OVERALL DESCRIPTION

An aircraft arriving within a TMA negotiates a 3D trajectory and a CTA before reaching the Top of Descent (TOD). Then the aircraft flies according to the agreed trajectory and respects the CTA constraint thanks to a speed regulation performed by the FMS.

The EPOPEE A/C flight plan is based on RNAV. To challenge RTA capability of the FMS, the most demanding configuration[3] has been chosen:

- No level-off between the Top of Descent and the CTA waypoint (i.e. the waypoint where the time constraint is set);
- The CTA waypoint is below FL100.

The CTA shall be uplinked to the A/C before the Top of Descent. Indeed, the [$ETA_{min,}$ $ETA_{max}$] window for which a CTA can be satisfied, that is to say “time control authority”[4] to meet controlled time, is not wide enough when the A/C is in descent phase. So, it is assumed that AMAN horizon (active advisory horizon) will extend to En-Route airspace.

Note: The scenario has been designed to demonstrate airborne and ground performances and not to be fully operationally representative from a controller perspective. Even if no specific separation problem was anticipated, it has not been for example ensured that this

[3] Less deceleration / speed adjustment scope when level segment absent, FMS do not regulate below FL 100 …

[4] Technically is rather speed control authority to meet the controlled time

could not happen. However, it has been ensured that the results obtained are relevant in a representative operational environment.

## 3.3 Detailed Description

The scenario uses the flight plan described in Annex but starts 20 minutes before the Top of Descent. All involved aircraft are airborne.

The EPOPEE A/C establishes CPDLC and ADS-C connections.

At the beginning of the scenario, the actual arrival route is not yet defined in the FMS of the EPOPEE A/C.

A first CPDLC route clearance ("UM83"), corresponding to the flight plan arrival route, is provided to the pilot.

The pilot uploads and activates this route in the FMS.

The new 4D trajectory (ADS-C "Extended Projected Profile" (EPP) group) is downlinked to the ATC.

On the MCDU, the pilot requests winds and temperatures to AOC, leading to an update of the data.

The 4D trajectory is updated, taking into account the new wind and temperature data, and downlinked to the ATC.

The controller requests the EUROCAT system to display the list of flights planned to fly over LARPO:

- Flight TR6001, coming from OMAKO, is estimated over LARPO at To (RTA)
- EPOPEE aircraft is estimated over LARPO at To+90".
- Flight TR6004 is estimated over LARPO at To+4.5' (RTA).
- ATC uses a speed control technique for TR6003 to separate it from the EPOPEE A/C towards the merge point. There is no RTA but the flight is expected to arrive at LARPO 90 sec behind EPOPEE.

TR6001 and TR6004 are equipped with RTA capability (i.e. they will actually fly over LARPO at the estimated time). They are using a STAR different from the EPOPEE aircraft STAR (MOU5E VIA LARPO), merging at LARPO[5].

[5] For technical demonstration purposes this validation scenario seems to depart from the Initial 4D concept descriptions where a point further out (E.g. IAF) would more likely be used as CTA point.

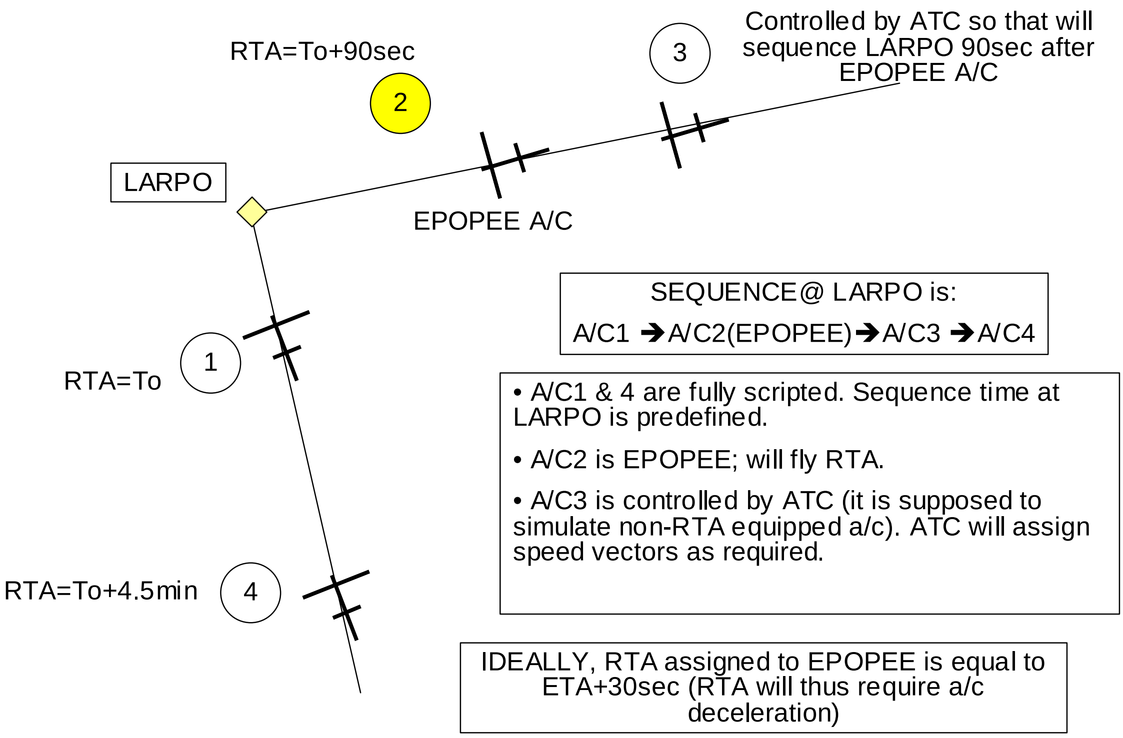


**Figure 3-1 – Initial 4D scenario**

The controller prepares a pre-sequence of aircraft over LARPO[6]. In order to implement the sequence he/she asks the EPOPEE A/C to indicate the $ETA_{min}$ and $ETA_{max}$ it could respect at LARPO.

The airborne system automatically answers the controller with $ETA_{min}$ and $ETA_{max}$ over LARPO via ADS-C (thus transparent to the crew).

Around 10 minutes before Top of Descent, the controller gives a CTA to the EPOPEE aircraft at To+120"' (+30" later regarding current estimation) over LARPO, compatible with $ETA_{min}$ and $ETA_{max}$. The ground system sends a CPDLC uplink message corresponding to this action.

The pilot waits for the uplink message to be displayed on the DCDU and loads the message in the FMS.

The pilot sends a WILCO message[7] to the ground system.

The FMS re-computes the trajectory and downlinks the recomputed trajectory.

The ground system takes into account the new trajectory.

---

[6] There is no AMAN to optimize inbound stream and no consideration is devoted to wake turbulence categories

[7] WILCO message "Will be Complied with": is a message send by a pilot to confirm that he/she is agreed with message from controller and he/she will be complied with

The controller manages via speed clearances the TR6003 flight that follows the EPOPEE aircraft in order to continue to respect a 90" spacing with it.

The controller gives level clearances to the EPOPEE A/C so that it is able to continuously descend without level off.

**Alternative#1:**

The EPOPEE A/C respects the CTA with required +/-10sec CTA accuracy.

**Alternative#2:**

The EPOPEE aircraft is not able to comply with the CTA (discrepancy between airborne meteo data and real meteo conditions, higher than CTA meteo error robustness requirement).

Either the ground or airborne side can detect the "CTA missed" event. When the CTA is predicted "missed", either a new CTA can be negotiated (typically when the a/c is in cruise phase) or the ATC controller can revert to non-CTA operations via speed/lateral vectoring (typically the case when the a/c is in descent phase, close to the CTA point).

Later on, the controller gives a new CTA following the same principle.



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# 4 SCENARIO 3 – ASAS SPACING "REMAIN BEHIND" AND "MERGE THEN REMAIN BEHIND"

## 4.1 OBJECTIVE

The objectives of this scenario are:

- To consolidate the description of the ASPA S&M operations (collect issues to be confirmed / discussed with controllers),
- To confirm the technical feasibility and assess the on board acceptability of onboard ASPA S&M function for two of the three possible manoeuvres: "Remain behind" and "Merge then Remain behind"

## 4.2 OVERALL DESCRIPTION

To build the arrival sequence and have it maintained during the descent down to the approach, the controller has to insert the EPOPEE aircraft N seconds behind a target aircraft (typically: 60 to around 200[8] seconds).

The controller uses one of the ASPA S&M instructions in order to fine tune and maintain the sequence he/she started to build (either manually or thanks to a pre-sequencing technique like Initial 4D) so as to sequence EPOPEE aircraft N seconds after the target aircraft.

Then either the requested manoeuvre is correctly operated, or an unexpected behaviour of the target leads the EPOPEE aircraft to fail the following of the target A/C.

Therefore, two sub-scenarios are foreseen:

- 3-a: Nominal case.

  A "**remain behind**" or a "**merge then remain behind**" instruction can be given to the EPOPEE A/C since the pre-sequencing was successfully done by the controller; the "**remaining**" phase of the scenario runs correctly without specific difficulty;

- 3-b: Alternative case.

  A first ASAS sequencing & merging instruction is given ("**remain behind**" or "**merge then remain behind**") that EPOPEE A/C cannot comply with. The flight crew informs it to the controller who gives another S&M instruction.

Whatever the scenario, each time an ASAS sequencing & merging instruction is given by the controller to the A/C, the S&M manoeuvre is carried out in two steps:

- Spacing establishment;
- Maintaining of the spacing.

[8] This value was chosen to be able to insert an additional aircraft further downstream in the sequence (so spacing between two aircraft when this downstream merge occurs becomes ~100 sec / ~10 Nm)

Each S&M instruction is given via datalink communication. CPDLC message contains all the elements used to perform a manoeuvre.

The Ground System provides the controller with the possibility to manage the ASAS S&M dialogue with the aircrew in one or two steps: the controller can first request to the aircrew to select the target, second to instruct the aircrew the ASAS manoeuvres relatively to this target, but the controller can also group the target selection and the ASAS instruction in a single command. These two different ways for initiating the ASAS manoeuvres will be discussed with controllers when running the scenario.

## 4.3 DETAILED DESCRIPTION

The scenario takes place at the end of cruise and then in descent and approach phases in a medium or high-density airspace: the instructed time spacing value is between 60 and around 200 seconds.

The flight crew on EPOPEE A/C is asked by the controller to identify the target A/C for which an ASAS S&M clearance will be issued.

The controller manages the EPOPEE descent by giving level instruction.

**Alternative#1:**

The controller gives the EPOPEE A/C a "**remain behind**" instruction. The flight crew engages the manoeuvre.

The acquisition and the maintaining of the spacing occur without specific difficulty.

**Alternative#2:**

*Event 1*: **Merge then remain behind** manoeuvre with a failed acquisition phase.

The controller gives the EPOPEE A/C a first "Merge then Remain behind" instruction. The flight crew engages the manoeuvre.

After a few minutes, the flight crew is notified of the inability by the EPOPEE A/C to acquire the instructed spacing at the merge waypoint due to the target A/C behaviour (its speed has changed outside the range of EPOPEE A/C performance envelope).

*Event 2*: **Merge then remain behind** manoeuvre with flaps extension and loc/glide capture

The controller gives the EPOPEE A/C a second "**Merge then Remain behind**" instruction. The EPOPEE A/C has no difficulty to acquire and maintain the instructed spacing.

In both alternatives the scenario ends once EPOPEE A/C has landed.

Note: this scenario was run during the Initial Scope Phase with reduced simulation means and without the EUROCAT system.

# 5 SCENARIO 4 – ASAS SPACING "HEADING THEN MERGE AND REMAIN BEHIND"

## 5.1 OBJECTIVE

The objectives of this scenario are:

- To consolidate the description of the ASPA S&M operations (collect issues to be confirmed / discussed with controllers),
- To confirm the technical feasibility and assess the on board acceptability of onboard ASPA S&M function for the third manoeuvre: "Heading then Merge and Remain behind"

## 5.2 OVERALL DESCRIPTION

To build the arrival sequence and have it maintained during the descent down to the approach, the controller has to insert the EPOPEE aircraft N seconds after a target aircraft (typically: 60 to around 200[9] seconds).

The controller uses one of the ASPA S&M instructions in order to fine tune and maintain the sequence he/she started to build (either manually or thanks to a pre-sequencing technique like Initial 4D) so as to sequence EPOPEE aircraft N seconds after the target aircraft.

The EUROCAT system exploits the 4D-trajectory downlinked by the aircraft to enhance its own time and altitude profile predictions. All flights are not descending by default with the same profile, and their spacing is not completely optimized on the converging point.

Therefore, from this point onwards, the controller will change the control procedure, using ASPA S&M instructions in order, first to adjust the spacing, then to maintain it between aircraft down to the final approach fix. As in scenario 3, the controller has to insert then maintain the EPOPEE aircraft 180 seconds after a target aircraft then 90 seconds behind another one inserted in the string further on the path to the FAF. The experimented ASAS S&M manoeuvre will be the 3rd one "Heading then Merge and Remain behind".

Then either the requested manoeuvre is correctly operated or, an unexpected behaviour from the target leads the EPOPEE A/C to fail the following of the target A/C.

Nominal cases are played for each manoeuvre:

- A S&M instruction can be given to the EPOPEE A/C since the pre-sequencing was successfully done by the controller; the "remaining" phase of the scenario runs correctly without specific difficulty;

Whatever the scenario, each time an S&M instruction is given from the controller to the A/C, the S&M manoeuvre is done in two steps:

- Spacing establishment;

[9] This value was chosen to be able to insert an additional aircraft further downstream in the sequence (so spacing between two aircraft when this downstream merge occurs becomes ~100 sec / ~10 Nm)

- Maintaining of the spacing.

Each S&M instruction is given via datalink communication. CPDLC message contains all the elements used to perform a manoeuvre. This part will also discuss with controllers.

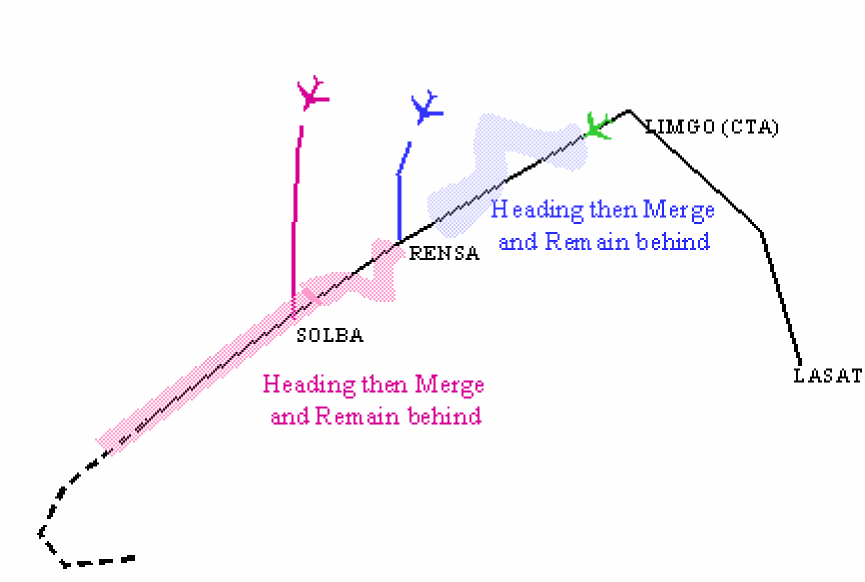


**Figure 5-1 – ASAS Spacing - 2 scenario**

## 5.3 DETAILED DESCRIPTION

The scenario takes place at the end of cruise and then in descent and approach phases in a medium or high-density airspace.

The scenario uses for EPOPEE A/C (flight identification **AIB001**) the flight plan described in Appendix 1, but starts on the airway UN852 before LIMGO, i.e. close from the Top of Descent. Its actual arrival route is already defined in FMS, following UN852 until LIMGO then RENSA and the STAR RENS4E. AIB001 is flying in vertical managed mode. All other aircraft involved directly in the scenario are airborne, following routes that will rejoin AIB001 at RENSA or SOLBA.

The ATC system receives surveillance and ADS-B data for all aircraft, including AIB001 and AIB001 provides as well the ATC system with an “ADS-C” 4D predicted trajectory. EPOPEE A/C is connected in CPDLC with the ATC system.

The controller manages the EPOPEE descent by giving level instruction.

**First ASAS manoeuvre**

When the simulation starts, AIB001 is expected to cross the point **RENSA** at a time that is about 180 seconds after the estimated time of over-fly of the flight **DLH4344**.

But AIB001 and the other flight DLH4344 have an expected time spacing from RENSA that become smaller than the planned one, necessitating an intervention of the controller for delaying AIB001 on RENSA. Due to the proximity of this point, the controller will select an ASAS S&M “Heading then Merge and Remain behind” manoeuvre as follows:

```
SELECT TARGET DLH4344 TURN RIGHT HDG NNN THEN MERGE AT RENSA
AND REMAIN 180 BEHIND TARGET
```

(Target Selection and ASAS S&M clearances will be sent in a single CPDLC uplink message, NNN represent the Heading that will be keyed in by the controller)

The CPDLC clearance will be displayed on the DCDU. Then, the flight crew will select the cleared heading on FCU and pull (making the flight change to a lateral mode). When established on the heading the flight crew will LOAD the clearance, check the feasibility of the manoeuvre by the traffic computer and the FMS, activate the ASAS sequencing & merging manoeuvre and finally, send the WILCO in response to the controller CPDLC clearance.

Then the EPOPEE A/C will automatically perform the manoeuvre, turning to the merge point at a time computed by the FMS.

On the controller position, a link will be displayed between the target A/C and the instructed aircraft for monitoring the pair of involved aircraft and the progress of the manoeuvre. The controller will have the possibility to display the 2D trajectory reported by the aircraft and therefore visualise the aircraft path until the merge point as well as its Estimated Time Over this point.

After crossing RENSA, merge point of the first ASAS sequencing & merging manoeuvre, EPOPEE A/C will remain spaced from DLH4344 for a while, following in lateral its STAR RENS4E. The controller will clear to the aircrew to descend to the altitude FL110 and the AIB001 aircraft will cope simultaneously with the altitude constraint and the ASAS manoeuvre in progress.

**Transition from the first ASAS manoeuvre to the second one**

While EPOPEE A/C is in the approach of a subsequent merge point, SOLBA, the controller will insert another flight (**AFR0566**, converging from the north) in the sequence between DLH4344 and AIB001.

She/he will first cancel the current ASAS sequencing & merging manoeuvre by voice.

The EPOPEE aircrew will then cancel the manoeuvre, temporarily returning to a selected-speed mode (using the current speed as the selected speed).

Once the first manoeuvre is cancelled, the controller will initiate the new one. Again the ASAS sequencing & merging 3rd manoeuvre HEADING THEN MERGE AND REMAIN BEHIND will be selected:

```
SELECT TARGET AFR0566 TURN LEFT HDG NNN THEN MERGE AT SOLBA AND
REMAIN 090 BEHIND TARGET
```

The EPOPEE aircrew will load and accept the clearance the same way as for the first manoeuvre.

Then the ASAS manoeuvre will continue until an automatic cancellation on board, when the aircraft reaches the altitude of 2000 feet.

During the simulation, the controller will also issue clearances to the ATG pseudo pilot for the other aircraft involved in the scenario (speed and level clearances).

In an alternative scenario, the controller might issue to the pseudo pilot, instead of speed adjustment clearances, instructions for ASAS S&M manoeuvres (only “REMAIN BEHIND” or “MERGE THEN REMAIN BEHIND” manoeuvres): in such a case the pilot will have to adjust by himself the speed of the corresponding aircraft to comply with the requested spacing.

The scenario ends once EPOPEE A/C has sequenced the second merge waypoint.

# 6 SCENARIO 5 – TRANSITION FROM CTA CONSTRAINT TO ASAS S&M OPERATION

## 6.1 OBJECTIVE

The objectives of this scenario are:

- To confirm the technical feasibility and assess the on-board acceptability of a transition from an Initial 4D procedure based on a CTA to an ASPA S&M procedure for one of the following possible manoeuvres: “Heading then Merge and Remain behind”;
- To confirm that such transition is manageable for the ATC controller. Notably, the scenario will allow investigating the ability for the controller to perform such transition in a smooth way and to continue to optimise the sequence of aircraft after having delegated the spacing to the respective aircrews.

## 6.2 OVERALL DESCRIPTION

To build the arrival sequence and have it maintained during the descent down to the approach, the controller has to insert the EPOPEE aircraft in medium-density airspace.

The controller starts to build a sequence thanks to a pre-sequencing technique like Initial 4D.

A CTA is sent to EPOPEE A/C on a specific waypoint via CPDLC.

The EUROCAT system exploits the 4D-trajectory downlinked by the aircraft to enhance its own time and altitude profile predictions.

All flights are not descending by default with the same profile, and their spacing is not completely optimized on the sequencing point. Therefore, from this point onwards, the controller will change the control procedure, using one of the ASPA S&M instructions in order, first to adjust the spacing then to maintain it between aircraft down to the final approach fix.

As in scenario 3, the controller has to insert then maintain the EPOPEE aircraft 180 seconds behind a target aircraft then 90 seconds behind another one inserted in the string further on the path to the FAF. The experimented ASAS S&M manoeuvres will be the “Merge then Remain behind” and “Remain behind”.

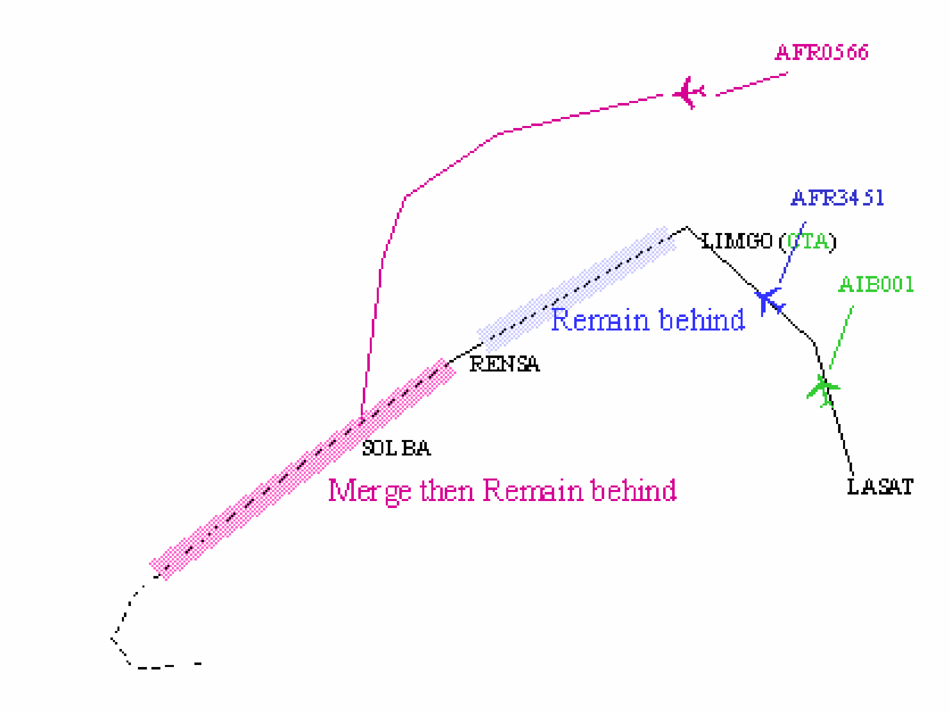


**Figure 6-1 – Transition from CTA constraint to ASAS S&M operation scenario**

## 6.3 DETAILED DESCRIPTION

The scenario takes place at the end of cruise and then in descent and approach phases in a medium or high-density airspace.

The scenario uses for EPOPEE A/C (flight identification **AIB001**) the flight plan described in Appendix 1, but starts on the airway UN852 at LASAT about 20 minutes before the Top of Descent. Its actual arrival route is already defined in FMS, following UN852 until LIMGO then RENSA and the STAR RENS4E. AIB001 is flying in FULL MANAGED mode. All other aircraft involved directly in the scenario are airborne, but at this time they are away from AIB001.

The ATC system receives surveillance and ADS-B data for all aircraft, including AIB001, and AIB001 also provides the ATC system with an "ADS-C" 4D predicted trajectory. EPOPEE A/C is connected in CPDLC with the ATC system.

As soon as the simulation starts, the controller will initiate a CTA clearance via CPDLC to the EPOPEE A/C flight crew for crossing the point **LIMGO** at a time that is 150 seconds after the estimated time of over-fly of the flight **AFR3451**.

**Transition from Initial 4D procedure to ASAS manoeuvre**

AIB001 will respect correctly the time constraint; nevertheless, the time spacing with the other flight AFR3451 on RENSA will be slightly different from the planned one, necessitating an intervention of the controller for delaying AIB001 once the point LIMGO is crossed. Because AFR3451 is following the same route as AIB001, the controller will select an ASAS S&M "Remain behind" manoeuvre as follows:

```
SELECT TARGET AFR3451 THEN REMAIN 150 BEHIND TARGET
```

(Target Selection and ASAS S&M clearances will be sent in a single CPDLC uplink message)

The CPDLC clearance will be displayed on the DCDU. Then, the flight crew will check the feasibility of the manoeuvre, activate the ASAS manoeuvre and finally, send the WILCO in response to the controller CPDLC clearance.

Then the EPOPEE A/C will automatically perform the manoeuvre, following the target at 150 seconds on its STAR RENS4E.

On the controller position, a link will be displayed between target A/C and instructed aircraft for monitoring the pair of involved aircraft and the progress of the manoeuvre.

The controller will clear the aircrew to descend to the altitude FL110 and the AIB001 aircraft will cope simultaneously with the altitude constraint and the ASAS manoeuvre in progress.

**Transition from an ASAS manoeuvre to another**

While EPOPEE A/C is arriving over RENSA the controller will cancel the current ASAS manoeuvre of AIB001, instructing the pilot to terminate the ASAS manoeuvre. The aircrew will cancel the manoeuvre, making return temporarily in selected speed on the current speed. Then on a subsequent merge point, SOLBA, the controller will insert another flight (**CPA2870**, converging on SOLBA from the north) in the sequence between AFR3451 and AIB001.

This time, because the other aircraft is not following the same route (it will still have not crossed SOLBA at this moment) the ASAS sequencing & merging 2nd manoeuvre MERGE THEN REMAIN BEHIND will be selected:

```
SELECT TARGET CPA2870 THEN MERGE AT SOLBA AND REMAIN 090 BEHIND
TARGET
```

The EPOPEE flight crew will load and accept the clearance in the same way as for the first manoeuvre.

Then the ASAS sequencing & merging manoeuvre will continue until an automatic cancellation on board, when the aircraft reaches the altitude of 2,000 feet.

# 7 SCENARIO 6 – 4D AIRBORNE NAVIGATION CAPABILITY FOR CTA / RNP

## 7.1 OBJECTIVE

The main objective of this scenario is to validate the following requirement defined in EP3 Requirements for Technical Validation [2]

| **[E3-AIR-4D-TRAJ-10]** | |
|---|---|
| **Requirement title** | **RTA accuracy in descent** |

FMS RTA function required accuracy / reliability shall be ±10sec, 95% of the time for any descent waypoint (located down to FAF).

The scenario will focus on the influence of wind and temperature, which are the most significant contributors to the ability of the aircraft to reach an RTA.

To validate this kind of performance requirement, a large sample of flights is necessary to get a statistical result. Using a Real time Simulation with a pilot in the loop is not cost effective. Therefore, a batch tool has been developed, allowing the run of several simulated flights without any operator action during the flights. A second objective of this scenario is to validate the use of this batch tool as a test mean to measure FMS performances.

## 7.2 OVERALL DESCRIPTION

To get credibility of the measurements performed by the batch tool, this tool shall use realistic models both for the product under test (the FMS) and the simulation environment. The FMS model is the same simulated FMS as the one provided by THALES AVIONICS for the technical validation platform. The aircraft model is the A340 model provided by Airbus (refer to EP3 Overall description of the platform [1]).

The batch tool can run several batch scenarios (a batch scenario is defined as one simulated flight). The purpose is to use differing deviations between forecast and current winds and temperatures (constant values used across the whole trajectory) for each batch scenario. The framework is similar to the one used during the evaluation of Initial 4D (see paragraph 3):

- The simulated plane is airborne in the en-route flight phase, some Nautical miles before the Top of Descent.
- The pilot enters in the FMS an RTA over a given RTA waypoint (the RTA value belongs to the [$ETA_{min,}$ $ETA_{max}$] window)
- The simulated plane flies until the RTA waypoint.

The batch tool simulates all the required pilot actions.

A batch scenario stops when the simulated plane flies over the RTA waypoint: the batch tool records the delta between the RTA waypoint overfly time and the requested RTA. The result is considered as successful if the delta is less than 10 seconds.

Note: the batch tool also records the ETA and [$ETA_{min,}$ $ETA_{max}$] window over the RTA waypoint during the flight. It could be useful to analyse the FMS behaviour during the batch scenario.

The batch tool consolidates the results of each batch scenario to have a measure of the RTA performance (95% of RTA met).

## 7.3 DETAILED DESCRIPTION

The batch tool allows running several batch scenarios. Each batch scenario is characterized by a set of modifiable parameters:

- Flight plan route
- Cruise FL
- Location where the flight is initialized, expressed as a distance to Top of Descent
- FMS values for wind and temperature
- Waypoint where the RTA is set
- Value of RTA, expressed as a percentage of ETA-ETAmin (negative value) or of ETA-ETAmax (positive value) at flight initialisation.

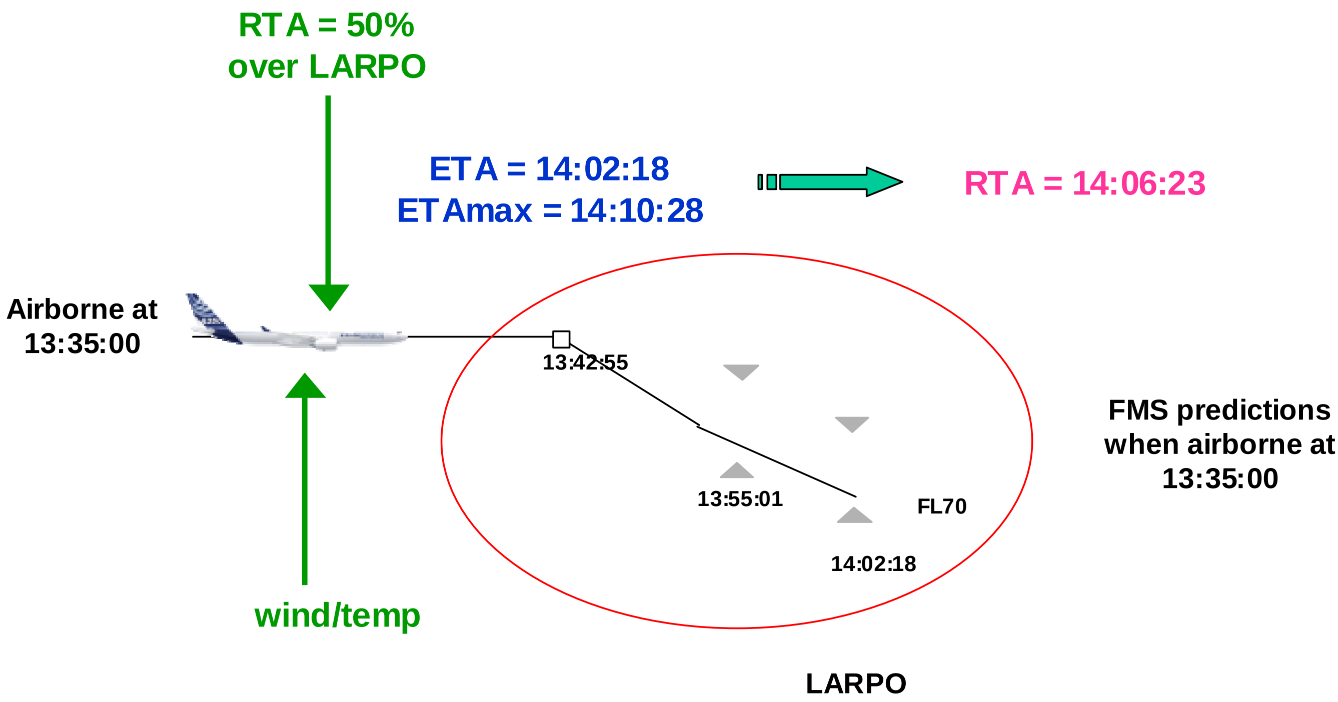


**Figure 7-1 – Example of RTA definition in batch tool**

All the batch scenarios contained in one batch may have different values for these parameters.

The Cost Index is the same for all the batch scenarios. It is set to 0.

Note: the wind and temperature values entered in the FMS are considered as wind and temperature errors because it is not possible yet to define wind and temperature in the simulation environment.

The exercise will be limited to the influence of wind and temperature errors. Therefore, the following parameters will be fixed for all the batch scenarios:

- Flight plan route
- Cruise FL
- Location where the flight is initialized
- Waypoint where the RTA is set

The flight plan route is the same as the one used for EPOPEE Aircraft in Initial 4D evaluation (refer to Annex). The flight is airborne and starts 50 NM before the Top of Descent.

Due to schedule constraint, only RTA waypoint below FL100 is investigated. It corresponds to the most demanding case from the FMS point of view since it is below the level where a speed limit applies. The RTA waypoint is LARPO as in the Initial 4D evaluation.

Test cases are defined to evaluate the influence of wind and temperature errors. A test case is a batch where wind and temperature errors are the same for all the batch scenarios, and the RTA values vary between $ETA_{min}$ and $ETA_{max}$. The wind and temperature errors will be different between two test cases.

To carry out the performance validation, a distribution of wind and temperature errors should have been performed. It has not been possible in the scope of the EP3 WP6.4.1– 4D Airborne Navigation Capability for CTA / RNP exercise. Due to schedule constraint, only limit cases can be investigated. Therefore, the results of this exercise cannot be considered as a validation of the requirement, but as a good trend. It will allow identifying and explaining each deviation between the FMS behaviour and the requirement. At this stage of validation, it can be considered as sufficient to achieve the TRL3 level (which corresponds to end of phase V2 / beginning of phase V3 of E-EOCVM; for TRL definition, please refer to EP3 Requirements for Technical Validation [2]).

The following test cases are defined for wind and temperature errors:

- 10 Kt headwind
- 10 Kt tailwind
- 10 Kt headwind, -4℃
- 10 Kt tailwind, +4℃

Note: A 10kt headwind entered in the FMS corresponds to a 10kt tailwind error. Indeed, the FMS predictions take into account the 10kt headwind while the simulated wind in the simulation environment is null. It means that the simulated Aircraft will fly faster than expected by the FMS. So the FMS will adjust the speed to slow down the Aircraft.

For each test case, 21 batch scenarios are defined with RTA values evenly distributed from $ETA_{min}$ to $ETA_{max}$ by step of 10% (i.e. $ETA_{min}$, 90% of ETA-$ETA_{min,}$ …, ETA, …, 90% of $ETA_{max}$ -ETA, $ETA_{max}$).

For each batch scenario, the batch tool will print a diagram showing the evolution along the flight of ETA, $ETA_{min}$ and $ETA_{max}$ predicted by the FMS over the RTA waypoint.

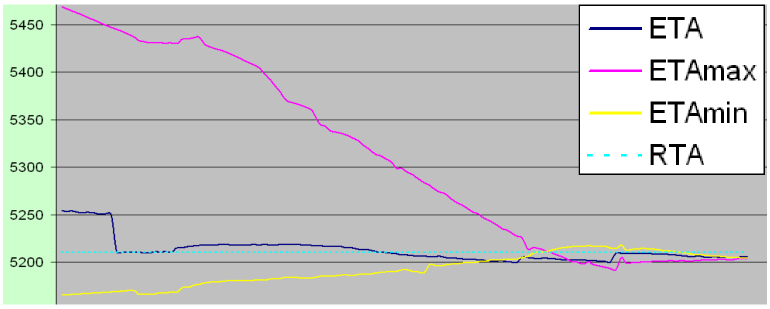


**Figure 7-2 – Example of batch tool printout for one flight**

To be able to evaluate the impact of wind and temperature errors, each test case will correspond to one batch. Therefore the scenario for exercise EP3 WP6.4.1– 4D Airborne Navigation Capability for CTA / RNP will be made of 4 batches, each batch containing 21 flights. For one batch, the batch tool will print a diagram showing the delta between the RTA and RTA waypoint actual overfly time

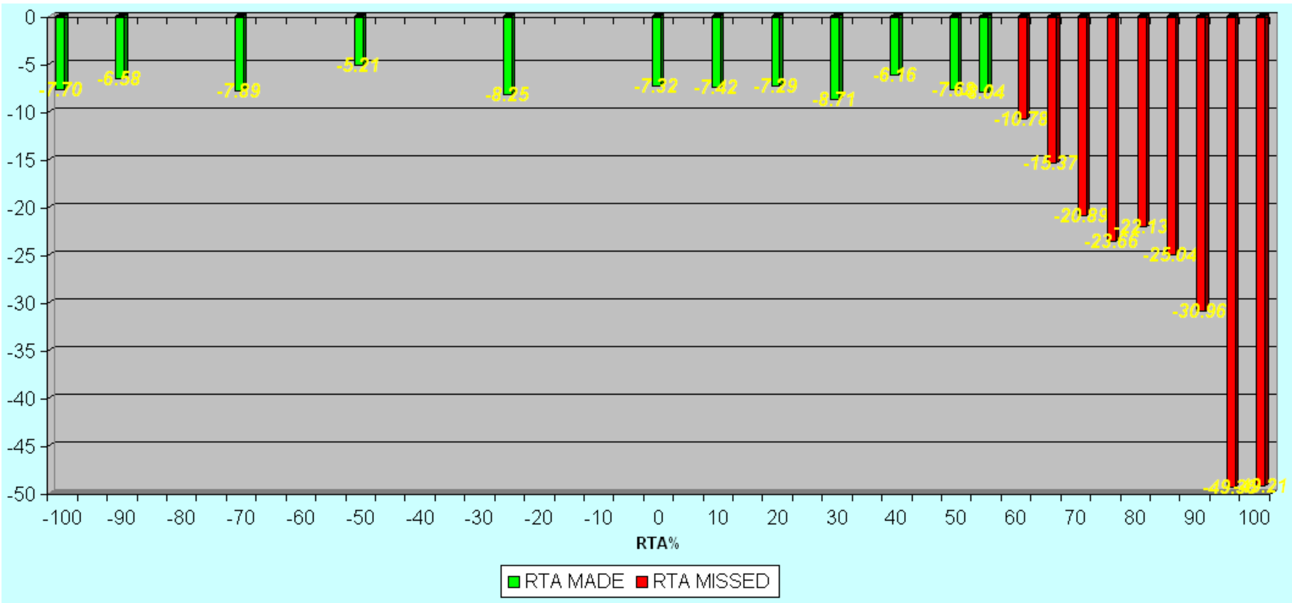


**Figure 7-3 – Example of batch tool printout for one batch**

# 8 REFERENCES AND APPLICABLE DOCUMENTS

## 8.1 REFERENCES

**[1] Episode 3** Overall description of the platform and its capabilities D6.2-01,

**[2] Episode 3** Requirements for technical validation D6.3-01

**[3] Episode 3** Prototyping of a dense TMA Consolidated Plan D5.3.6-01

**[4] EUROCONTROL** 4DTRAD OSED draft 0.38

**[5] EUROCONTROL** 4DTRAD CONOPS issue 1, December, 1st 2008

**[6] ICAO** PANS-ATM Doc 4444 (Rules of the Air and Air Traffic Services)

**[7] ICAO** PANS-ATM Doc 9694 Part III - Draft11 (ADS-C) (Manual of Air Traffic Services (ATS) Data Link Applications)

**[8] ICAO** OPLINKP/1-WP/33 Appendix L (CPDLC Guidance Material) to the Report CPDLC Guidance Material

**[9] ICAO** Doc 9694 - The Manual of Air Traffic Services Data Link Applications

**[10] EUROCONTROL** EATM - DAP/SPR - LINK 2000+ PROGRAMME - BASELINE

**[11] EUROCONTROL** EATM - DAP/CSP - LINK 2000+ PROGRAMME - ATC Data Link Manual for Link 2000+ Services - version 4.0

**[12] RFG** Package I – Enhanced Sequencing and Merging Operations (ASPA S&M) - Application Description v2.3 20 - Jan-2009

## 8.2 APPLICABLE DOCUMENTS

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

# ANNEX - FLIGHT PLAN FOR INITIAL 4D EVALUATIONS

## A.1 TRAFFIC CHARACTERISTICS:

Arrival at Paris Charles De Gaulle (LFPG), STAR and ILS Approach on runway 9L with the following characteristics:

- RNAV until runway threshold
- Limited constraining levels
- Merge point LARPO (for 2 arrival flows) before the glide capture, corresponding to a flight level 70, then descent to the ILS with a level off at altitude 3000ft.

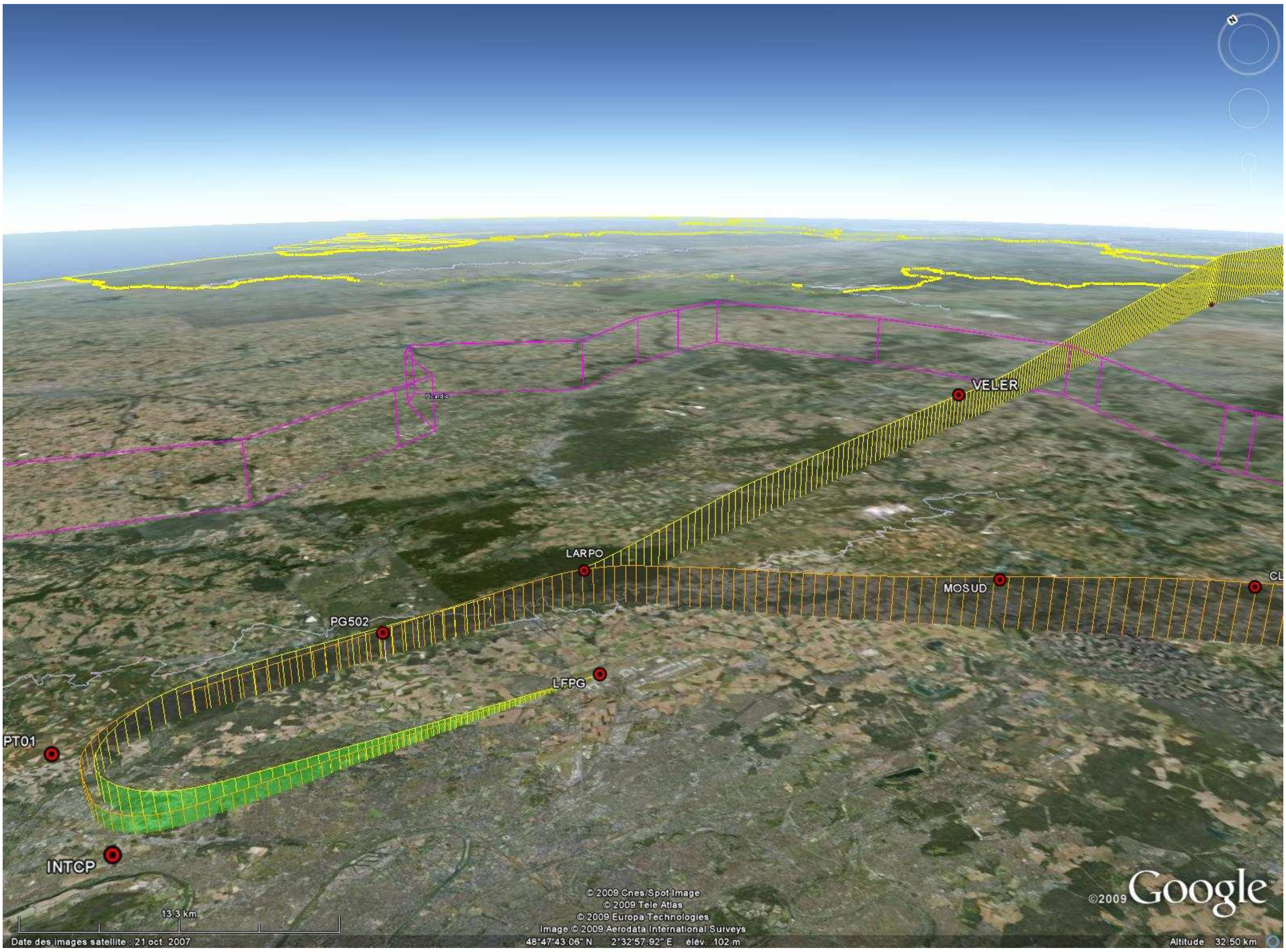


**Figure 8-1 – Initial 4D flight plans**

## A.2 EPOPEE A/C FLIGHT PLAN

Departure: Nice (LFMN) runway 22R

SID: PERU3X (AMIRO PERUS with no ATC constraint)

Route: PERUS A3[10] RETNO UN852 LIMGO RENSA

Cruise FL = 360

STAR: RENSA4E (modified as follow: RENSA GIMER D075Y SOLBA VELER/F110)

To limit constraining levels the vertical profile of STAR RENSA4E is modified as follows:

| | Existing Alt Cstr | Existing Speed Cstr | New alt cstr | New speed cstr |
|---|---|---|---|---|
| RENSA | --- | --- | --- | --- |
| BSN60 | --- | 280kts | --- | --- |
| BS38A | FL140 | 250kts | --- | --- |
| GIMER | --- | --- | --- | --- |
| BSN25 | FL110 | --- | --- | --- |
| SOLBA | --- | --- | --- | --- |
| VELER | FL110 | 250kts | FL110 | --- |

**Figure 8-2 – Initial 4D - STAR modification**

VIA VELER (VELER BSN LARPO PG502 WPT01 INTCP CI09L) with a level constraint of FL070 on LARPO and 3000ft on CI09L.

Additional waypoints have been inserted after PG502 to suppress radar-vectoring part (from PG502 until LOC capture) and allow RNAV until runway threshold. The vertical profile is also modified to limit constraining levels.

Additional Wpts

| | | | | |
|---|---|---|---|---|
| VELER | FL110 | 250kts | FL110 | --- |
| BSN | --- | --- | --- | --- |
| LARPO | --- | 220kts | FL070 | --- |
| PG502 | --- | --- | --- | --- |
| WPT01 | N/A | N/A | --- | --- |
| INTCP | N/A | N/A | --- | --- |
| CI09L | N/A | N/A | 3000ft | |

**Figure 8-3 – Initial 4D - VIA modification**

**Approach Procedure: ILS09L** (CI09L FI09L RW09L)

[10] (But A3 is an airway that is theoretically used only at Low Level!)

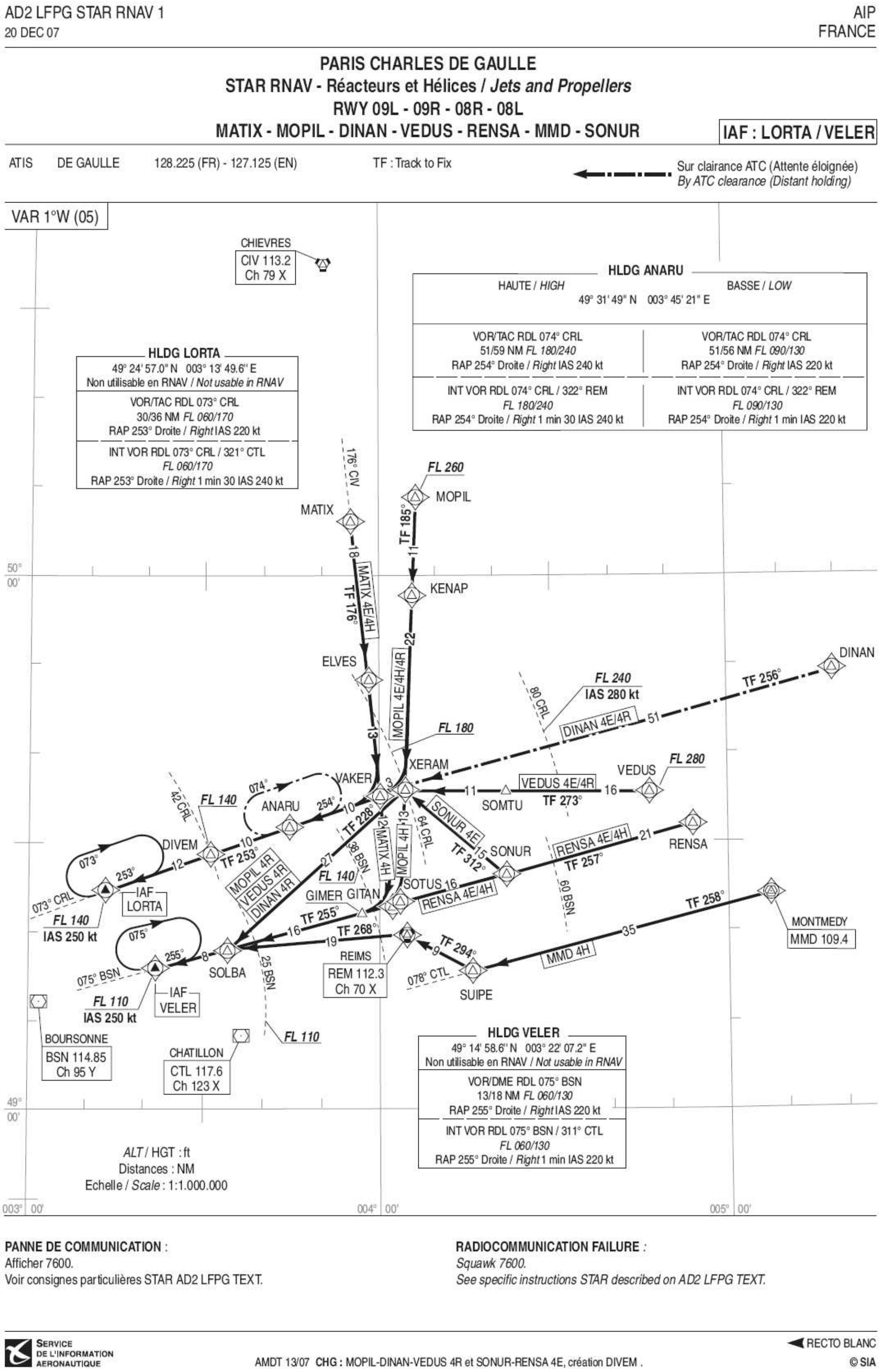


**Figure 8-4 – Initial 4D - STAR for EPOPEE A/C**

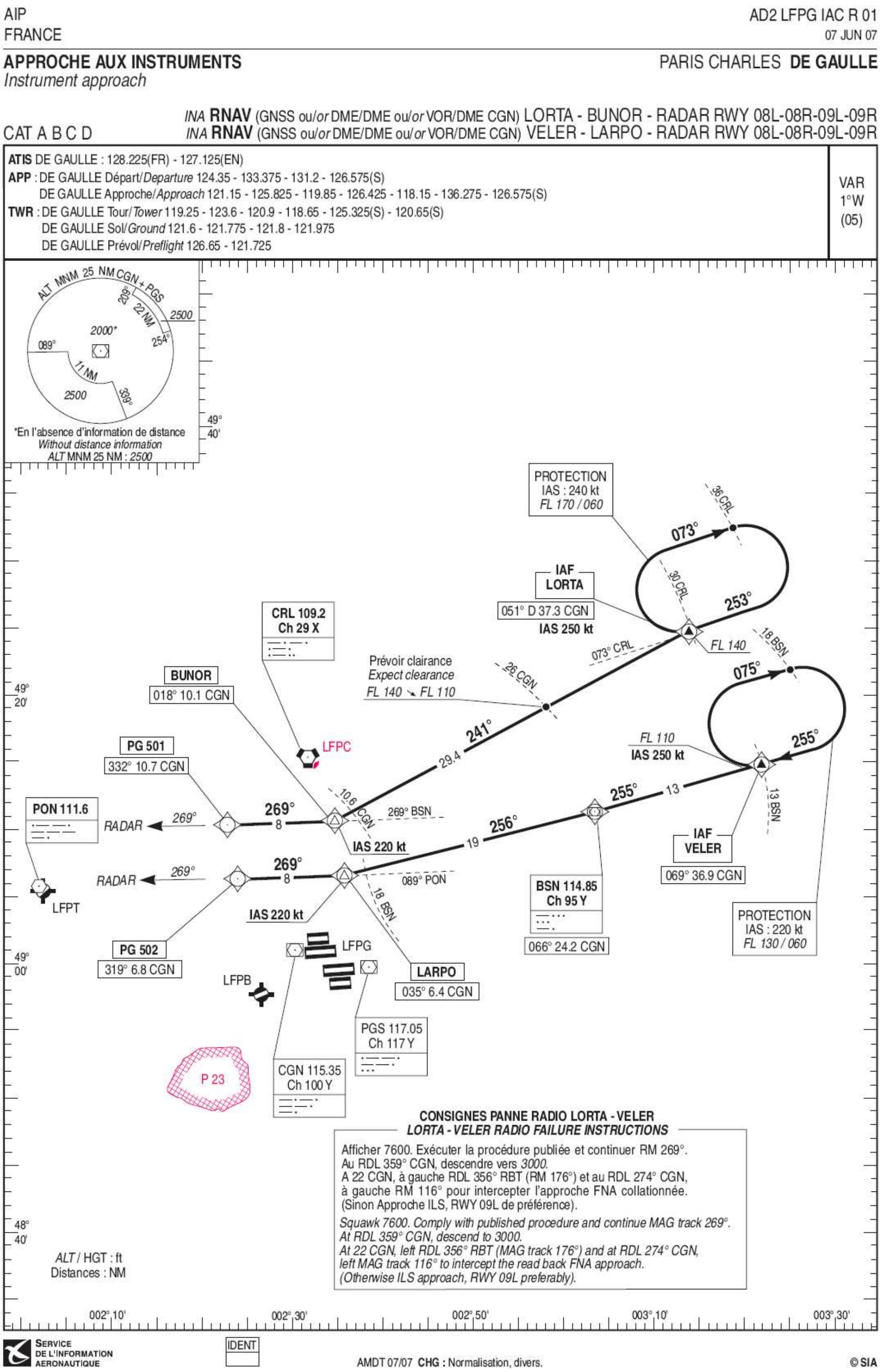


**Figure 8-5 – Initial 4D – VIA for EPOPEE A/C**

## A.3 MERGING TRAFFIC

Traffic Merging with EPOPEE A/C at LARPO uses STAR MOU5E VIA LARPO

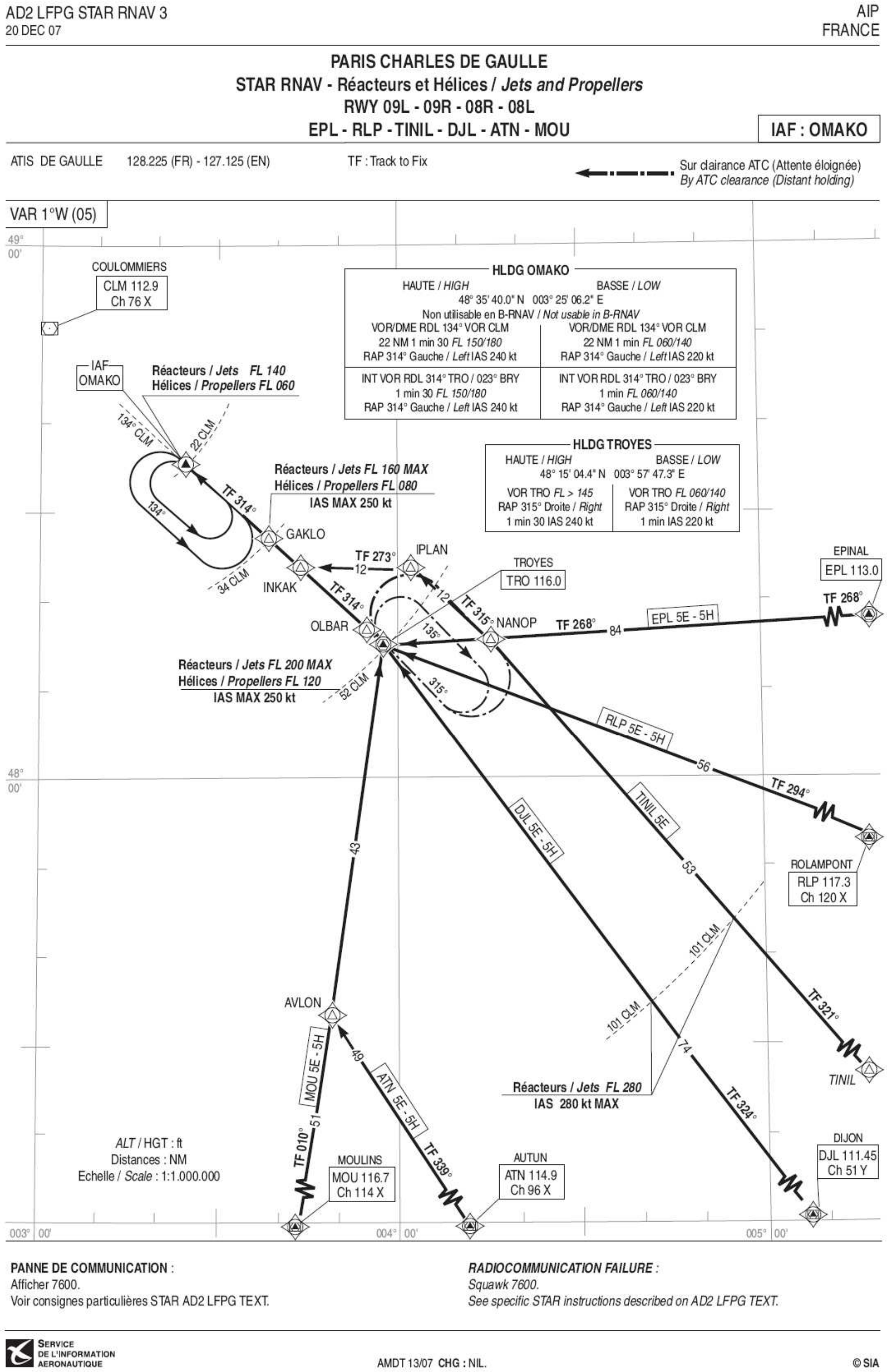


**Figure 8-6 – Initial 4D - STAR for merging traffic**

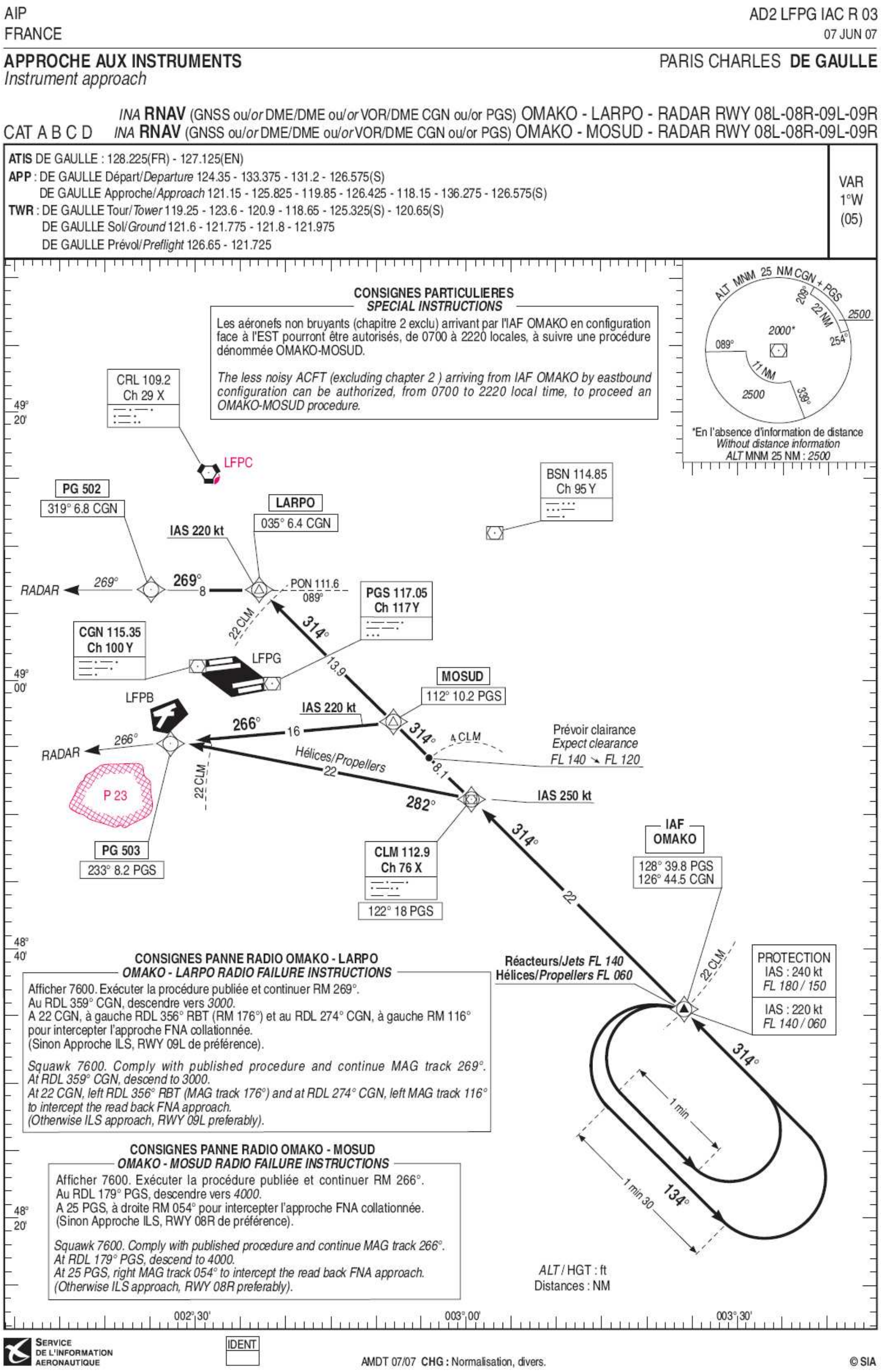


**Figure 8-7 – Initial 4D - VIA for merging traffic**

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