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AIRE-II Final Result Report

Trajectory Based Night Time CDA's at Schiphol Airport

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Executive Summary

This document provides an overview of the background, concept of operation, phased approach and results of the AIRE-II project "Trajectory Based Night Time CDA's at Schiphol Airport".
In the AIRE-II project KLM, LVNL and NLR have demonstrated a system innovation during night time operations to enable inbound traffic to fly undisturbed Continuous Descent Arrivals/Approaches (CDA) at Schiphol Airport.
The innovation consisted of a pre-planning system which supports the air traffic controller in his/her task to plan inbound traffic streams such that the percentage of CDA flights with an ideal profile increases. The pre-planning system was fed with down-linked trajectory data from the aircraft that includes Estimated Times of Arrival (ETA) for one or more points on the route. This data was used to make an optimized pre-planning of traffic landing in the 04:00am to 06:00am (local time) timeframe. The planning was presented to the air traffic controllers (ATCOs) of LVNL with the aim to detect and solve planning conflicts amongst inbound aircraft.
Aircraft that were inbound Schiphol in the target test period received a Planned Time of Arrival (PTA) to coordinate and manage the arrival traffic stream. These PTA's were generated by the pre-planner and validated by the ATCOs of LVNL. The communication of the PTA well before top of descent (TOD) allowed aircraft to anticipate in a very early stage what is expected to eliminate *bunching* (PTAs were handed out typically 60 minutes before landing).

The goal of the AIRE-II trials has been to demonstrate, in a phased way, the pre-planning process that aims to improve overall operational efficiency and controller workload. It has been the intention of the trials to use the benefits of a pre-sequenced arrival stream to allow for more CDAs from top of descent.

It has been shown that the concept of pre-planning works. Traffic bunches have been prevented resulting in more efficient descent profiles. In total 10 airlines and 124 flights were involved in these AIRE II trials. On a yearly basis the fuel benefit indicator is 0.50 kilo tonnes, this equates to approx 74 kg fuel per flight.
On the path towards the preparation and execution of live ATC/flight trials of these time based operations, many useful lessons have been learned (related to the concept of operation, data exchange, data quality, flight crew and air traffic controller involvement, setting up and executing live trials); these are disseminated through this document.

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1 Introduction

In the AIRE-II project KLM, the Dutch air navigation service provider LVNL and the Dutch Aerospace Laboratory NLR have demonstrated a system innovation during night time operations to enable inbound traffic to fly undisturbed Continuous Descent Arrivals/Approaches (CDA) at Schiphol Airport.
The innovation consisted of a pre-planning system which supports the air traffic controller in his/her task to plan inbound traffic streams such that the percentage of CDA flights with an ideal profile increases. The pre-planning system was fed with down-linked trajectory data from the aircraft that includes Estimated Times of Arrival (ETA) for one or more points on the route. This data was used to make an optimized pre-planning of traffic landing in the 04:00am to 06:00am (local time) timeframe. The planning was presented to the air traffic controllers (ATCOs) of LVNL with the aim to detect and solve planning conflicts amongst inbound aircraft.
Aircraft that were inbound Schiphol in the target test period received a Planned Time of Arrival (PTA) to coordinate and manage the arrival traffic stream. These PTA's were generated by the pre-planner and validated by the ATCOs of LVNL. The communication of the PTA[1] well before top of descent (TOD) allowed aircraft to anticipate in a very early stage which is expected to reduce or even eliminate *bunching* (PTAs were handed out typically 60 minutes before landing).
The goal of the trial has been to improve overall operational efficiency, both in terms of fuel savings / emission reduction and in terms of controller workload. It has been the intention of the trial to use the benefits of a pre-sequenced arrival stream to allow for more CDAs from top of descent.

This report describes the results of the trial executed in November 2011 and also elaborates on the experiences of the project team gained during the execution of the project.

1.1 Background

The Atlantic Interoperability Initiative to Reduce Emissions (AIRE) is a programme designed to improve energy efficiency and lower engine emissions and aircraft noise in cooperation with the FAA. The SESAR JU is responsible for its management from a European perspective.
Under this initiative ATM stakeholders work collaboratively to perform integrated flight trials and demonstrations validating solutions for the reduction of CO_2 emissions for surface, terminal and oceanic operations to substantially accelerate the pace of change. The strategy

[1] A PTA is not a clearance as opposed to a Controlled Time of Arrival (CTA).

is to produce constant step-wise improvements, to be implemented by each partner in order to contribute to reaching the common objective. The SESAR JU selected 18 projects involving 40 airline, airport, ANSP and industry partners to expand the AIRE in 2010/11.

The trial "Trajectory Based Night Time CDA's Schiphol Airport" is part of the AIRE-II call for tender which was launched in January 14, 2010 (SJU/LC/0039-CFP). In response to this call a consortium consisting of KLM, NLR and LVNL submitted a proposal to perform flight trial at Schiphol airport with the aim to reduce emissions. The SJU awarded the consortium with a contract to prepare and perform the trial in the 2010 – 2011 timeframe (SJU/LC/0128-CTR). The project kick-off was 26 August 2010.

1.2 Document Layout

In Chapter 2 the concept is detailed, in Chapter 3 the execution of the project is described in detail. Chapter 4 describes the results of the four test nights. In Chapter 5 lessons learned and open issues are presented. Finally, in Chapter 6 conclusions are drawn and directions for future work are given.

2 The concept

This chapter provides some background information, describes the rationale of the project and gives a brief overview of the activities performed.

2.1 Rationale

Today, air traffic control is primarily based on ICAO flight plans and ‘current state’ surveillance data assuming aircraft performance and given actual and forecast weather. Differences between the estimated intent and actual realization affect the stability and predictability of traffic flows. Furthermore, traffic is handled on an ATC sector-to-sector basis, effectively partitioning the flight execution based on ATC sector boundaries. This partitioning in combination with limited availability of intent information constrains the controller’s ability to optimize across boundaries.

The ATM community in Europe [ref SESAR, D3 The ATM Target Concept] and the U.S. [ref NextGen Air Transportation System] have adopted the concept of Trajectory Based Operations (TBO) (also called Trajectory Management) and System Wide Information Management (SWIM) as a potential solution to increase ATM efficiency. In SESAR, the “Business Trajectory” is proposed as the basis for such trajectory operations. The business trajectory, a 4D trajectory which expresses the business or mission intentions of the airspace user, including any prevailing constraints, is the SESAR designation of what is referred to as ‘4D Trajectory’ in the Trajectory Based Night Time CDA concept of this project. It is built from, and updated with, the most timely and accurate data available.

The TBO concept proposes the use of aircraft 4D trajectory data which is shared using SWIM and agreed between all relevant actors. All modern commercial aircraft today have FMSs that generate the aircraft intended trajectory data which can be closed-loop executed by the aircraft flight control system. It is expected that using FMS trajectory data and functions in combination with SWIM will contribute to more stable, predictable, efficient and environmentally friendly operations.

The impact, issues and benefits of the SESAR Trajectory Management concept and SWIM are subject of extensive research in the SESAR development phase. The implementation according to the e-ATM Masterplan has commenced under supervision of the SESAR Joint Undertaking (S-JU). The modernization of Europe’s Air Traffic Management (ATM) structure builds on 4 pillars:

1. increase the capacity
2. lower the cost for airspace users

3. increase safety levels
4. lower environmental impact

The AIRE program and subsequently the AIRE trial at Schiphol focuses around the fourth pillar: lower the environmental impact. This impact consists of several components such as fuel burn (that result in CO_2 and NOx emissions) and noise production. By optimising air traffic management (ATM) services, SESAR's target for 2020 is to save 10% fuel per flight which leads to a 10% reduction of CO_2 emissions per flight.

Several causes can be distinguished as to why ATM is currently sub-optimal in terms of efficiency and environmental impact. Since the European airspace is the most fragmented airspace in the world, the potential benefits achieved through cooperation to optimize the ATM system are high. Because of this current lack of integration, the maximum potential of existing technology in terms of efficiency and environmental impact is often not reached. Therefore, the introduction of new technology is not always a prerequisite to optimize ATM. The potential powerful combination of existing technology and cooperation between stakeholders is an important enabler to further optimize the ATM system.

The Atlantic Interoperability Initiative to Reduce Emissions (AIRE) is a partnership between the FAA and the EC. This initiative aims to reduce CO_2 emissions by executing pre-operational validation projects that can be immediately deployed. The technology currently used in the ATM system has undisputedly brought large improvements to ATM. Using this technology to its full extent however is often hindered by barriers that come from existing procedures, mixed equipage levels and/or airspace fragmentation. One of these barriers is the (lack of) cooperation between stakeholders. The AIRE initiative recognizes that cooperation is an important enabler for further optimizing the ATM system and reducing CO_2 emissions. By using present-day technology, the AIRE initiative ensures that the path towards the execution of a validation plan is relatively short and therefore flight-trials can be part of these projects to determine their effectiveness.

2.2 AIRE Trajectory Based Night Time CDAs

In this AIRE-II project KLM, ATC the Netherlands and NLR introduced a system innovation during night time operations to enable inbound traffic to fly an undisturbed CDA at Schiphol Airport. Maastricht Upper Area Control (MUAC), the National Air Traffic Services (NATS) and Delta Airlines provided assistance to the team wherever possible. Flying undisturbed CDAs from Top of Descent (TOD) is often hindered by multiple aircraft arriving at more or less the same time (”bunching”). To prevent conflicts, the air traffic controller (ATCO) needs to intervene and as a result the CDA is not fully achieved.

The innovation consisted of a pre-planning system which supports the air traffic controller in his/her task to plan inbound traffic streams such that the percentage of CDA flights with an ideal profile increases. The pre-planning system was fed with down-linked trajectory data from the aircraft that includes Estimated Times of Arrival (ETA) for one or more points on the route. This data was used to make an optimized pre-planning of traffic landing in the 04:00am to 06:00am (local time) timeframe. The planning was presented to the ATCOs of ATC the Netherlands. In addition the planning was shared and coordinated with MUAC.

The communication of the Planned Time of Arrival[2] (PTA) well before TOD allowed aircraft to anticipate in a very early stage which was expected to eliminate the bunching. The rationale behind this was that aircraft that know their PTA would control towards this PTA (closed-loop) resulting in a “natural” de-confliction that eliminated the necessity for vectoring. This allowed aircraft to execute their CDA as efficiently as possible.

Currently, aircraft that are behind schedule may increase their cost index to make up time only to find that they are part of a bunch and need to be vectored (or even need to hold) when entering the FIR. Early communication of the PTA would eliminate such inefficient operation. The trial consisted of an operation which managed aircraft that enter the Dutch FIR. The project team strived for including all traffic in the flight trials that arrived at Schiphol in the timeframe.

About 65% of the flights in the time-frame were from KLM and participated in the trials. All other airlines that had inbound flights within the time-frame were invited to participate in the trials as well (either using data-link or R/T). Aircraft with no direct data-link with the planning system are referred to as *non-connected*. Obviously the project team strived to keep the number of non-connected aircraft as low as possible as non-connected aircraft clearly increase controller workload.

LVNL in coordination with adjacent centres endeavoured to provide a clearance onto a fixed arrival route for runway 18R or 06 well in advance of top of descent. A fixed arrival route is important to obtain a reliable ETA from the aircraft. This fixed arrival route consisted of the relevant transition to the runway in use preferably preceded by a “direct-to” leg to the Initial

[2] A PTA is not a clearance as opposed to a CTA.

Approach Fix (IAF). Traffic that participated in the trial aimed to meet the pre-planned runway threshold crossing time.

3 Project approach

This chapter provides an overview of the execution of the project, the steps taken, the caveats and problems encountered.

3.1 Project Phasing

The SJU divides the project in two phases: phase 1 (creation of detailed project plan) and a phase 2 (execution of the project). The project team has subsequently divided the SJU phase 2 in 4 additional phases (named phases 2 to 5).

As a consequence, the project had the following phasing: the first phase concerned the creation of the detailed project plan, concept of operations and the final communication plan. In the second phase the pre-planner, together with supporting systems was developed. The third phase was used to execute some preliminary field tests while in the fourth phase these tests were extended to full functional tests. Finally in the fifth phase extensive full night tests aimed at emission reduction were planned.

3.1.1 The first phase

The first phase of the project concerned the creation of the detailed project plan, concept of operations and communication plan. These have been published together in December 2010 as the results of work-package 2 under contract number SJU/LC/0128-CTR. Obviously, these documents formed the basis for the other phases. One of the main sources for creating these documents were the first two workshops held in November and December 2010 respectively (see Section 3.2).

While the above tasks were sufficient for the SJU defined first phase, the project team decided to start work on the next phase in parallel to save time. This was on own risk and cost as the SJU had the right to discontinue the project when phase 1 was unsatisfactory.

Current procedures were studied by the project team by observing active controllers during their nightly shifts. Technical studies were started to determine the details about the development of the connection between planning system and aircraft. Also some first ideas were proposed about the algorithms behind the planning system. An extensive traffic analysis was conducted to establish the fleet/airline mix that was active during the period of the trial. This analysis served a number of purposes:

- gain insight in amount of KLM flights
- know how many non-connected aircraft need to be dealt with
- be able to write procedures suitable for the amount of traffic
- be able to estimate the maximum performance of the planning system

- estimate the amount of bunching that occurs on average

3.1.2 The second phase

After a positive reception of the results of phase 1 by the SJU, the second phase could be quickly launched because of the preparations in phase 1. The main task of phase 2 was to create the foundation of the planning system. This included the set-up of the communication with KLM Operations Control Center (OCC) to be able to communicate with the KLM aircraft. For this set-up, first the message set necessary to communicate between aircraft and planning system was designed. These messages are sent to KLM OCC, translated to ACARS format and uplinked to the aircraft. Aircraft responses are down-linked to KLM OCC, translated to the proper message format and sent to the planning system.

In parallel the Human Machine Interface, which forms the link between the planning system and the air traffic controller, was designed and implemented (see Figure 1).

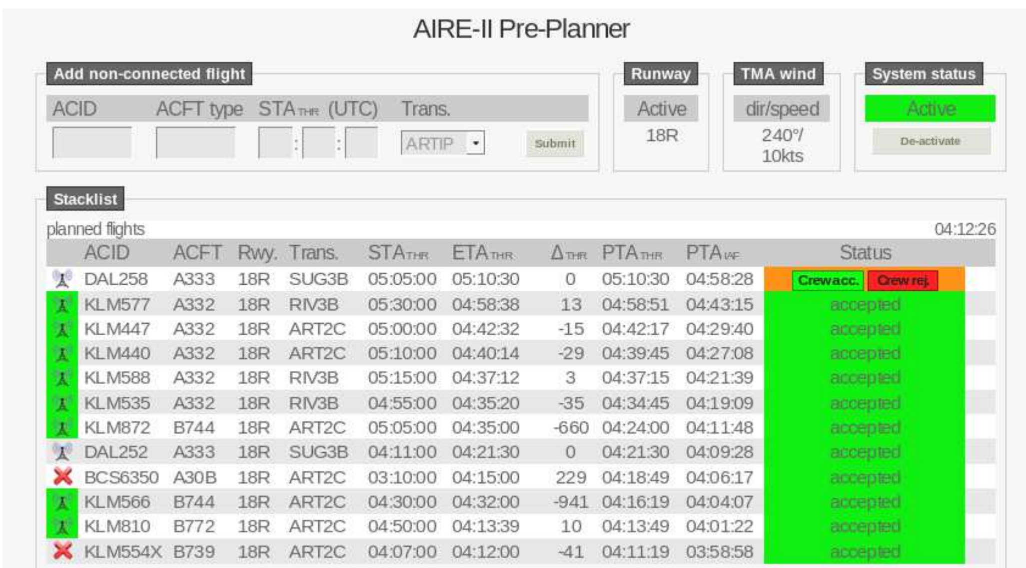

Figure 1: Screenshot of the Pre-Planner HMI

Finally, a module was added that has been used by Delta Airlines to enter aircraft derived data from their aircraft in the system. This enabled Delta Airlines to participate as a connected partner in the project even without a direct data-link. The integrated planning system is depicted in Figure 2.

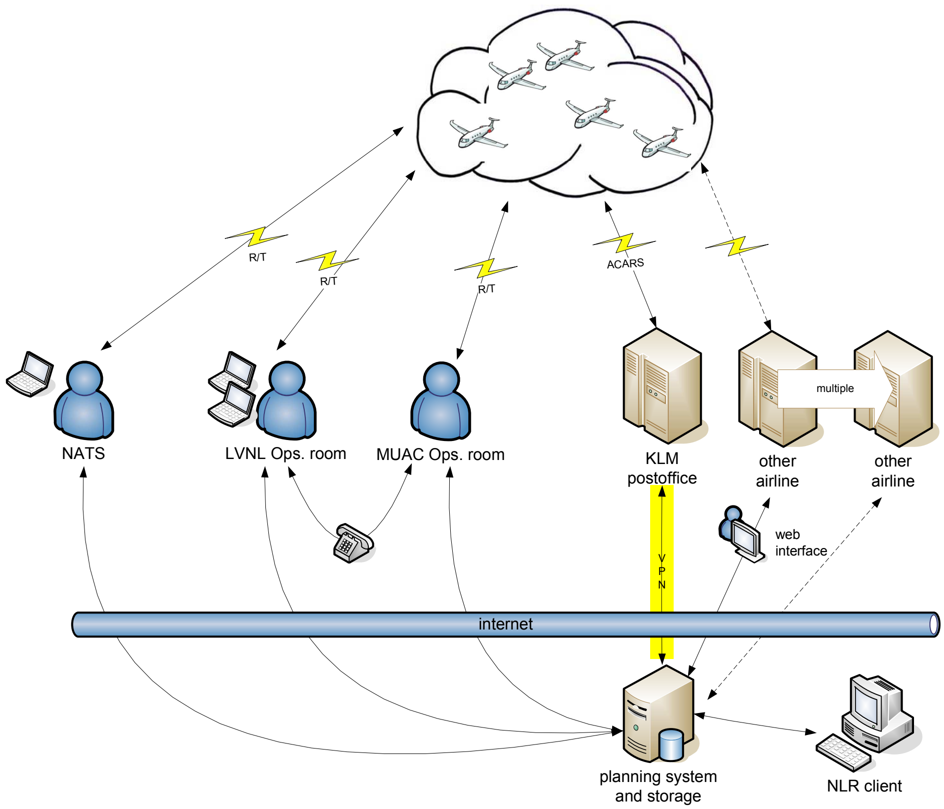

Figure 2: schematic view of the planning system

Phase 2 was concluded with extensive testing that verified the stability and functionality of the software. The results of this acceptance test have been described in Deliverable 3.1. The acceptance test report contains a comprehensive description of the software and its modules, a description of the flow of information through the system and a test report. The test report consists of more than 50 functional tests. The results of these tests have been fed back into the system design until the planning system was considered stable.

Next the data-link with airborne aircraft was tested. Specific flights were chosen for this purpose and the pilots were individually briefed how to respond. This test cycle started with some simple connection tests and ended with full functional tests in which the complete message cycle of a planning process was simulated. All aspects of the message exchange were tested with different types of aircraft. These test revealed many small but crucial differences in how aircraft responded to the messages. It became clear that each specific FMS version has its own peculiarities that should be dealt with by applying specific rules when sending the messages.

As for the procedures at ATC a start was made to create an extensive document describing the procedures for the air traffic controller when participating in the trial. Each and every situation that could occur during the trial should be covered in such a document. This document was finished before the phase 4 tests.

For the National Supervisory Authority (NSA) a document had to be created to describe the system changes necessary to accommodate the trial.

3.1.3 The third phase

The third phase test was held on May 11, 2011 at the LVNL facilities at Schiphol Oost. The test was conducted on the basis of version 1.0 of the phase 3 test plan “Influencing a Single Flight”.

The original plan was to have two separate tests, one for the 747 and one for the A330, if need be, on two different test days. As KLM did not have a 747 project pilot available in the April – May timeframe, it was decided to just test the A330. Two A330 project pilots were planned on an inbound night-flight on May 11 and it was decided to involve both flights in the test: one flight was treated as a non-connected and one was treated as a connected flight.

The test goal was to influence, with OPS involvement, a single flight, not (yet) relating the flight to any other flight. An important part of the test goal was to test the coordination procedure with MUAC for the so called non-connected flights. The phase-3 test is a functional test and does not have the goal to optimize the flight profile of an individual flight.

Despite the phase 2 tests, an unexpected response of one of the aircraft caused an interpretation error in the planning system and therefore no planned time of arrival was generated. In addition it became apparent that some parameter settings needed change and the coordination procedure with MUAC needed fine tuning as well. The tests performed on May 11 therefore turned out to be very useful, in the sense that they revealed a number of flaws in the system. It was concluded that the current state of the system was not sufficiently mature to transition to phase-4 testing. After system changes (and evaluation) another operational phase-3 test was considered necessary.

An extra phase-3 test was held on June 30, 2011 at the LVNL facilities at Schiphol Oost. The test was conducted on the basis of version 1.0 of the phase 3 test-plan “Influencing a Single Flight”. The test plan was summarized in an operational briefing “Draaiboek AIRE-2 fase 3, 29-30 juni, versie 1.1” (in Dutch).

MUAC was informed of the test but had no active involvement with the trial. Prior to the test it was clear that on June 30 some system testing was on-going at MUAC which prevented them from actively participating in the trial. As the tests focussed on automatic connected aircraft, no coordination with MUAC about ETA / PTA was necessary. Therefore it was decided to let the test go ahead without active MUAC involvement. Again two A330 flights were involved. An example of the cockpit prints are shown in Figure 3.

```
.PH-AOA ---- KLM428      30JUN11 0159Z
AIRE TRIAL MSG.
                            ACARS MSG
FLIGHT NO. KLM428                              A/C-ID .PH-AOA
PRINTED 30JUN11 0159                      FROM OCCOVKL 300159
-------------------------------------------------------------
                          AIRE TRIAL MSG.
REQUEST TO MANAGE A PLANNED TIME OF ARRIVAL (PTA) AT IAF
.
PTA AT IAF ARTIP 03:03:15 HR
.
PLEASE ACCEPT OR REJECT
.
END OF MESSAGE
```

```
.PH-AOA ---- KLM428      30JUN11 0138Z
AIRE TRIAL MSG.
                            ACARS MSG
FLIGHT NO. KLM428                              A/C-ID .PH-AOA
PRINTED 30JUN11 0138                      FROM OCCOVKL 300138
-------------------------------------------------------------
                          AIRE TRIAL MSG.
EXPECTED IAF TRANSITION AND RUNWAY
IAF:         ARTIP
TRANSITION:  ART2A
RUNWAY:      06
.
PLEASE ENTER COMPLETE FLIGHTPLAN IN FMC.
.
END OF MESSAGE
```

Figure 3: Examples of cockpit prints of the AIRE messages

The tests performed on June 30, were successful. The data exchange worked properly and the data was received timely. The project pilots concluded that the datalink communication was simple and self-explanatory for every pilot. On the basis of the phase 3 test results, the project team decided to move on with the phase 4 testing in October 2011.

3.1.4 The fourth phase

The original plan was to have only one fourth phase. However, because of bad weather in the first week, it was decided to split phase four in an A and B part.

3.1.4.1 Phase 4A

In the fourth phase a full system test was planned. This involved planning each flight within the timeframe of 0400-0600am local time in which each aircraft used the RTA function to execute the planning. The tests were executed during five consecutive nights from 8 October to 12 October. Unfortunately due to bad weather, only during the fifth night a full test could be executed. This fifth night turned out to be very useful though. A total of 16 flights were planned, 12 KLM flights and 4 DAL flights. Although the test night was successful, some fundamental issues came to light. The most important issue was the inability of the planning system to accurately estimate the flying time between IAF and threshold. Aircraft downlink a time at the threshold, while the planning system made a planning for the IAF. The flight time between IAF and threshold was estimated by a simple trajectory predictor. This turned out to be too inaccurate. Therefore a fundamental change was implemented that let the planning system plan at the threshold. Another issue had to do with pilot briefing. FMS programming turned out to be inconsistent among pilots. As a result aircraft behaviour was different than anticipated with inaccurate planning as a result. The planning horizon of 90 minutes turned out to be a source of some inaccuracies too. As is common during nightly operations, often aircraft get directs towards waypoints because of low traffic density. However, if an aircraft has already negotiated a PTA, accepting a direct can have the result that the PTA can no longer be maintained. This obviously results in inaccurate planning. As refusing a direct because of the trial is unacceptable (after all, the main driver of the trial is "greening"), it was decided to reduce the planning horizon to 60 minutes. This should still be enough for the aircraft to gain/lose some minutes while on the other hand directs can be accepted when offered. Finally a technical issue was observed that prevented Boeing 777 pilots to receive the planned time of arrival. The result of this was that 777 aircraft could not participate in the phase 4 trial.

Because of the limited amount of testing in phase 4 (just one night) and the issues that were identified, it was decided that instead of the emission reduction trial, another phase 4 test was necessary, this phase was called phase 4B.

3.1.4.2 Phase 4B

Phase 4B was conducted for 6 consecutive nights from 21 to 26 November 2011. The technical issues were solved, the procedural change to plan on the threshold was implemented and the briefing of the pilots was securely reviewed and adapted where necessary. Delta Airlines was completely in the loop now and therefore the DAL flights could be treated as "connected" flights. The first two days of the trial were again cancelled because of adverse weather. On the other four days however the trial could be executed. No new technical issues were observed, the planning system worked robust and stable. In Chapter 4 an extensive evaluation of these test nights is described.

3.1.5 The fifth phase

As a fifth phase, an emission reduction trial was planned (which involved lifting of altitude restrictions when entering the TMA). However, the original timeframe for test phase 5, November 2011, was used by the last full functional tests, phase 4B. Although test phase 4B was successful, it was apparent that changes were needed to the trial set-up and test systems to make it more effective to de-bunch aircraft. The project team proposed to execute test phase 5 directly after finishing phase 4B. This proposal was rejected by management for a number of reasons:

1. The trial set-up was considered to be ineffective to deal with the heavier bunches of aircraft.
2. A thorough evaluation of test phase 4B was deemed necessary before moving to the next phase.

The evaluation with controllers and pilots, with subsequent roster claim, could not be completed in time to execute test phase 5 within the timeframe of the contract (which ended at February 26, 2012). A request to further extend the contract would have been an option, but the project team felt that such a request would put too much pressure on the outcome of the evaluation of test phase 4B.

3.2 People and expertise involved in the project

The core team of the project consisted of representatives of the three project partners. As the system became more mature, more needed to become involved. The following table summarizes the experts and expertise involved and the project phases they were involved in.

Expert	**Expertise**	**Involved in phases**	**Remark**
Project management	Coordination among sites	1 to 5	
Technical experts	Data-link Algorithmic System design Middleware	1 to 4	
ATC operational experts		1 to 4	Active during definition and during trial
ATC procedural experts		1 to 3	Active during definition of the project
ATC executive controllers		3 to 5	Controllers active during the trial
Pilot experts		1to 4	
Executive pilot experts		3 to 5	Pilots active during tests and trials

Experiment leader	leads trial in ops room	4 to 5	

3.3 Adjacent centres

The two adjacent centres involved in the project were MUAC and NATS. To be able to have close to 100% participating aircraft in the trial, for aircraft that were not connected via data-link to the system procedures for cooperation with the adjacent centres MUAC and NATS were created. An exception were the DAL flights which were coordinated through the web-interface, see Section 3.4. The adjacent centres were brought into the loop as the Schiphol radar coverage is only a few minutes outside the Amsterdam FIR. This is by far insufficient for the 90 (and later 60) minutes horizon that was necessary for the trial. The procedures were aimed at getting the same information into the planning system as was available for the connected aircraft. Summarized, the procedure was as follows:

- the adjacent centre detected a non-connected aircraft on their radio (inbound Amsterdam)
- using R/T they requested the ETA threshold from the aircraft
- using a telephone line, they called ATC The Netherlands and provided the callsign and ETA
- the ATC controller in Amsterdam entered the information into the planning system
- the planning system generated a PTA
- the PTA was communicated back to the adjacent centre by telephone
- the PTA was communicated to the aircraft by the adjacent centre using R/T
- the pilot accepted or rejected the PTA
- the pilot response was communicated back to Amsterdam by telephone

The above procedure is very laborious. Because of the low number of non-connected aircraft and for the sake of the trial, this was acceptable. However for implementation of the concept this should be improved upon.

3.4 Other airlines

To increase the number of connected aircraft, the project team sought contact with all airlines that had one or more inbound aircraft in the trial timeframe. Each airline was informed about the trial, its goals (including the airline benefits) and what to expect. Nearly all airlines responded positive. As most airlines had only one or a few inbound aircraft in the period of the trial, it was decided that it was too much work to create direct data-link connections with all airlines. Therefore these aircraft were treated as non-connected and brought in the loop via the adjacent centres. Only Delta Airlines has multiple inbound aircraft in the timeframe. As Delta Airlines was very enthusiastic about the trial, they agreed to cooperate actively during the trial period. As a direct data-link with the aircraft was not

feasible, a solution was chosen in which a Delta employee contacted their aircraft well before the planning horizon and requested the necessary ETA information. They entered the information into the planning system using a web-based form. When passing the horizon the planning system generated the PTA and the Delta employee communicated the PTA back to the flight deck. Finally, he/she entered the crew response in the system.
For Amsterdam ATC, there was no visible difference between the connected aircraft and the aircraft that communicated via the web-based form. Therefore Delta aircraft could be treated as if they were connected to the system. This procedure considerably reduced the necessary amount of coordination with adjacent centres. Overall, the cooperation with Delta worked well although occasionally ETA information was entered into the system too early, resulting in inaccurate ETAs.

3.5 The workshops

In the course of the project, some workshops were held with technical and procedural experts, air traffic controllers and pilots. The first two workshops served two purposes: getting input from experts on the concept of operations and planning system and raising awareness and getting support for the trials. At the third workshop the results of phase 2 were presented to get feedback for phase 3. The amount of feedback was so high that a smaller fourth workshop was organized to continue discussions. Having all stakeholders and experts together in one room during the workshops turned out to be very beneficial for the project.

The first workshop

First a general presentation was given about the goals of the trial and the rough idea of the planning system and procedures. Some issues that were discussed included:

- concept of operations at LVNL and MUAC
- technical infra structure and message set
- how to deal with non-connected aircraft
- cockpit procedures

The second workshop

Using the results of the first workshop, the phased project setup was created. The results of the phased trial setup were discussed at the second workshop together with the consolidated concept. Comments were received and incorporated in the phase 1 documents.

The third workshop

The third workshop consisted of two sessions. The first session was aimed at the procedure analysis document (internal document) and collecting feedback from controllers and other

ATC experts. This document was presented and led to interesting discussions about the details of the trial. Valuable feedback and information was collected. The discussions were so intense that it was decided to continue them at an additional fourth workshop.
For the second session, KLM and NLR experts joined and discussions shifted towards technical matters and a presentation with experiences from phase 3 was given by a KLM captain to show a cockpit perspective on the trial.

The fourth workshop

A fourth workshop was held after phase 3. This (small) workshop was aimed at ATC, hence only controllers and other ATC experts attended. At the fourth workshop the current status of the project was presented, including a demonstration of the planning system. The workshop was held to continue discussions of the third workshop, to create awareness on the present state of the project, present the results of the first three project phases, present the details of phases 4 and 5 and to get feedback on the details of the procedures and planning system.
A demonstration of the planning system was given and controllers were informed about the next steps.

3.6 Trial evaluations

After phase 4A, an evaluation session was held with operational and procedural experts. The goal of this session was to discuss the results of the trial. A similar session was held at the end of the project to evaluate the project. Results of these sessions have been included in this document.

3.7 Dissemination

The dissemination strategy of the project has been defined in the communication plan. This plan has been executed, but some additional activities have been performed. First some articles were published in relevant aviation magazines such as CANSO's Airspace magazine Spring edition 2011. Another addition to the original plan was the creation of a promotional video. This video has already been shown at various booths at ATC Global 2012.

4 November 2011 trials

This chapter describes in detail the phase 4B trials as executed in November 2011. Phase 4B is described because the full potential of the pre-planning concept itself was tested for the first time during a number of consecutive nights. Compared to phase 4A the main changes involved the flight crew procedures and pre-planner system. These changes included communication of a PTA at runway threshold instead of IAF, connectivity of Delta Airlines, a pre-planner time horizon of 60 minutes instead of 80 minutes and filtering of unreliable ETA messages.

4.1 Goals of Phase-4

The primary goal of the phase-4 test was to build confidence[3] that the pre-planning process would help to create a stable inbound traffic stream without traffic bunches.

An important difference between phase 4 and phase 5 was that altitude and speed restrictions remained in effect during phase 4 whereas it was the intention to relax these restrictions during the emission reduction trial.

During phase-4 testing it was essential that inbound traffic was handled in a predictable manner. Therefore it was important that, traffic permitting, the involved flights executed their plan as programmed in the FMS[4]. It was expected that the involved flights would fly continuous descent profiles, taking altitude and speed restrictions into account during the descent.

4.2 Set-up of the Phase-4B trial

The trial ran for six consecutive nights. The LVNL procedures had been written in detail in a procedure design document for the LVNL controllers (in Dutch). The text below is an abstract of the procedure design document, and KLM's cockpit procedures.

Prior to each test night, a decision is taken by the ACC SUP whether or not to let the trial go-ahead for that night. This decision is taken after the evening briefing at 20:00 pm LT. The main criterion is whether or not there is a runway change expected during the test execution. In case the trial is called off, the experiment leader will notify all involved parties and personnel.

[3] It was not expected that the pre-planning process could solve **every** conceivable planning conflict. In fact when several aircraft have the exact same ETA for Schiphol, using speed control 60 minutes before ETA may be insufficient to de-conflict these aircraft.

[4] Note: the practice of adjacent centres to clear aircraft direct to the IAF was retained in test phase 4. For the majority of routes this practice created a small time inaccuracy which could be absorbed when flying to an RTA. For the (few) routes where a significant time effect occurred, a procedural solution was put in place.

In case a go-ahead is given for the following trial night, all staff needed for the trial execution is present in the LVNL OPS room, no later than 02:00 am LT. The pre-planning system is installed and activated prior to 02:00 am LT in coordination with the LVNL ISC department. KLM support staff is needed from 02:00 am LT onwards. MUAC and NATS support staff (if they elect to assign extra staff for the trial) is needed from 03:00 am LT onwards.

The flights which are planned to land at Schiphol in the target test time[5] (i.e. 04:00 until 05:30 LT) are retrieved from the CIFLO system and the relevant flight plan data is entered into the pre-planning system by the PPO. This process takes place between 02:00 am and 02:30 am LT. From 02:30 onwards, the adjacent centres can print the list of participating flights from the pre-planner web-page.

The PPO is located in the direct vicinity of the ACC exec controller to enable information sharing about the pre-planned sequence and to access the communication lines with adjacent centres for the coordination of non-connected aircraft.

Between 02:30 and 02:40 LT the pre-planning process starts when the pre-planner proposes the first PTA for an inbound aircraft. The PPO validates (“acknowledges”) the PTA before sending it to the OCC of the involved airline.

The PPO coordinates with NATS and MUAC, via a dedicated telephone line, for the incidental non-connected flights that are inbound Schiphol during the target test timeframe. The pre-planning process ends when the last PTA, of the last aircraft having an ETA before 05:30, has been processed. It is expected that the last PTA is processed before 04:10 LT for connected aircraft. An incidental non-connected aircraft can be planned as late as 04:50 LT (40 minutes before the close of the target time period, which is at 05:30 LT).

After the pre-planning process has ended, the information on the pre-planner (laptop) can serve as context information for the ACC exec controller. The ACC exec controller is not expected to assist the inbound aircraft in making their time over the runway threshold (the aircraft is expected to regulate their speed to meet the PTA at the runway). However, it is recommended that the ACC exec controller is informed about the planning information in the pre-planning system.

4.3 Planning of the Phase-4B trial

The trial was conducted during six consecutive nights starting in the night from November 20 to November 21 and ending in the night from November 25 to November 26.

The table below gives a general overview of these six test nights. As can be seen, the trial in November effectively consisted of only four successful test nights, however during these four nights the concept was tested in very different traffic conditions. These nights showed quite different traffic patterns, ranging from a night with some relatively simple planning conflicts, via a night with moderate traffic bunches, to a night with a really heavy traffic bunch.

Table 1: Conditions of the November tests

Test night	**Test summary**
21 Nov 2011	Cancelled. Transitions were not in use due to fog.
22 Nov 2011	Cancelled. Transitions were not in use due to fog.
23 Nov 2011	Testing from 04:00 to 06:00 LT. Runway in use 18R. Some de-bunching, but none of the B747s responded
24 Nov 2011	Testing from 04:00 to 06:00 LT. Runway in use 18R. Very good de-bunching.
25 Nov 2011	Testing from 04:00 to 06:00 LT. Runway in use 18R. Good de-bunching, but a very benign traffic pattern.
26 Nov 2011	Testing from 04:00 to 06:00 LT. Runway in use 18R. Some de-bunching. Heavy traffic bunch with unlucky pop-up traffic.

4.4 Results

4.4.1 General statistics

Figure 4 to Figure 7 present some general statistical data with respect to the four test nights of phase 4B. Figure 4 shows the total amount of inbound aircraft between 04:00 and 06:00 LT, it varies between 15 and 21 arrivals per night. In total 72 flights were involved in the November trial. The majority of the inbounds (71%) arrived via the Easterly Initial Approach Fix ARTIP. From the South (RIVER) and from the West (SUGOL) the number of arrivals per night varied between 2 and 4. The number of flights from the South and the West accounted for approximately 15% each.

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[5] An extra buffer of 15 minutes is taken around this time window, to cater for early flights or delayed flights to fall in the target test timeframe.

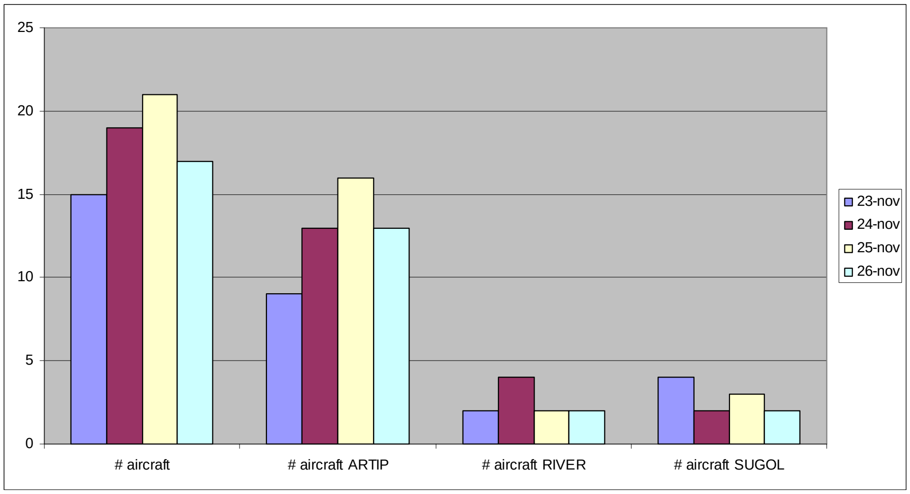


Figure 4: Number of aircraft during trial period and the distribution over the IAFs

Figure 5 presents the distribution of the inbound flights over the airlines. The KLM flights accounted for 65% of the total number of inbound flights during this test period; and the SkyTeam group (KLM, MPH, DAL) was responsible for 82% of the total number of flights. Table 2 provides an overview of the airlines that actively participated in these AIRE-II trials at Schiphol, i.e. the airlines that received a PTA. It can be concluded that all airlines were involved with exception of Air Contractors (airline code ABR). The ABR flights, flown with an ATR72, were not connected to the pre-planner and the voice procedure to include them in the pre-planning process was not deemed useful as the flights came from the South and therefore only flew for a very limited amount of time in MUAC airspace.

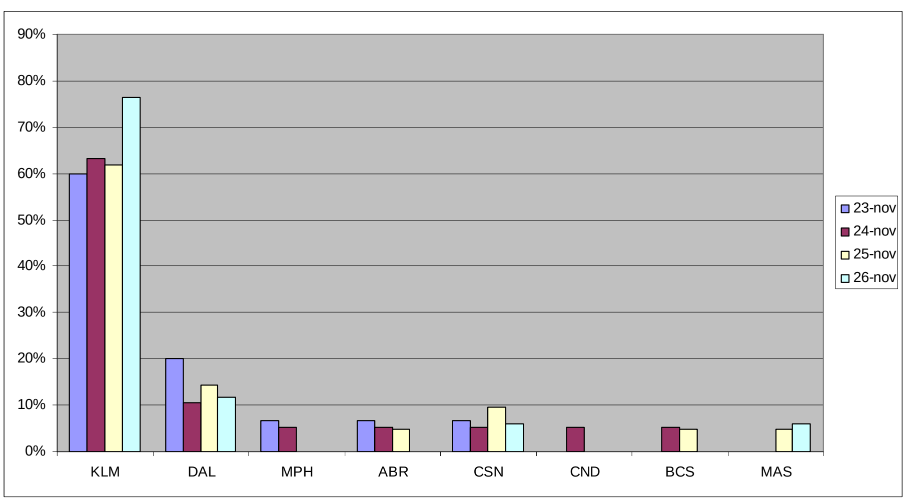


Figure 5: Distribution of airlines

Table 2: Overview of airlines that received a PTA (October and November trials)

Airline Code	**Airline**
KLM	KLM Royal Dutch Airlines
DAL	Delta Air Lines
MPH	Martinair
CSN	China Southern Airlines
CND	Corendon Dutch Airlines
BCS	European Air Transport
MAS	Malaysian Airlines
CAI	Corendon Airlines
SHY	Sky Airlines
TFL	Arkefly

The aircraft types that were observed during this test period are presented in Figure 6. The Airbus A330, Boeing 747 and Boeing 777 formed the majority (76%) of the inbound flights accounting for 33%, 30% and 13% of the total number of flights respectively. The Boeing 737NG, Boeing 767, Boeing MD11 and ATR72 formed the second group (21% in total) with respectively 7%, 6%, 4% and 4% of the total number of flights. Obviously, the distribution of the aircraft types was different for the various test nights.

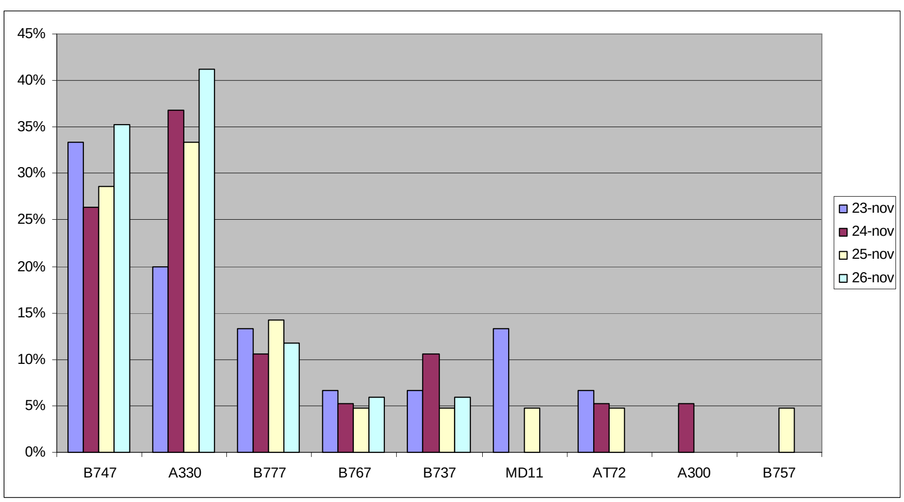


Figure 6: Distribution of aircraft types

The characteristics of the pre-planning process are illustrated in Figure 7. All parameters are expressed as percentages of the total number of inbound flights per test night.

A Planned Time of Arrival was generated for 90% of the inbound flights. Typically, each night no PTA was generated for one or two flights. These non-participating flights can be divided in three groups.

Firstly, the ABR flights (4%, 3 out of 72) from the South were not connected via datalink and also not inserted in the pre-planning process via manual coordination with MUAC (flights from the South are only a limited number of minutes under control of Maastricht prior to transfer to LVNL). This deficiency was known beforehand and accepted.

Secondly, non-connected aircraft are entered into the system prior to the start of the trial based on a so-called CIFLO list. Some aircraft were ahead of schedule and as a result their landing time was just inside the time interval of the trial. As their original planned time was not inside the time interval, they were not on the CIFLO list and they were not known by the system.

Finally, the ETA of one KLM flight was not received in time. This flight was a Boeing 747-400 for which the ETA was manually downlinked, however, because of an historic implementation decision at KLM OCC, only ETAs that differ more that 3 minutes were forwarded to the pre-planner.

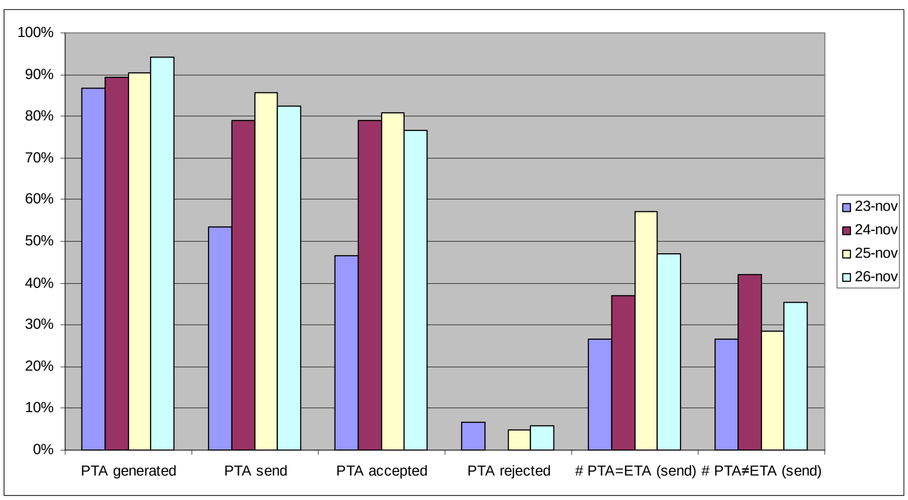


Figure 7: PTA characteristics

After generating a PTA, the controller is requested to approve it before it is sent to the aircraft. The number of PTAs actually sent by the controller was 85% of the generated PTAs. Especially in the first test night many generated PTAs were not validated and send by the controller. The main reason for not sending a PTA (9 out of 10 cases) was that in these cases the ETA of KLM B747-400 was received by the pre-planner only when the aircraft entered the Dutch FIR. The controller found it useless to transmit in such a late stage a PTA for these aircraft. During the first test night the ETA was not always sent by the flight crews and in all other cases the pre-planner didn't receive the downlinked ETA due to afore-mentioned logic: the manually downlinked ETA had to differ more than 3 minutes from a system-generated ETA in order to be forwarded to the pre-planner. A total number of 55 PTAs were sent to the aircraft during the November trial, 52 PTAs (95%) were accepted by the flight crews and 3 were rejected.

During night operations the aircraft always get a direct to by the adjacent sectors, typically to either the IAF (e.g. ARTIP) or the starting point of the Standard Arrival Route (e.g. NORKU or DENUT). During the November trial the pre-planner received FMS flight plan information from many KLM aircraft (MD11, A330 and B777). Table 3 shows the relationship between the time a PTA was generated and the time a direct to was entered in the FMS flight plan. Many flights (15 out of 24) still did get a direct instruction after PTA generation. It is observed that a direct ARTIP, after PTA generation, didn't strongly influence the pre-planning process. Aircraft accepted the direct to and continued to control to the PTA. Obviously, they had to slightly adapt their speeds to deal with the path shortening. Analysis prior to test phase 4 had shown that for the involved flights a direct ARTIP results in an ETA change in the order of 20-40 seconds. For aircraft from the South a direct DENUT did influence the pre-planning process. In three cases a direct DENUT was given after the PTA was generated, sent and accepted by the flight crew. In two of these three cases the PTA was subsequently rejected because the flight crew was unable to further reduce speed to make the PTA. In the third case the aircraft, although it didn't reject the PTA, couldn't slow down anymore and subsequently landed approx 3 minutes before the accepted PTA.
It is recommended to develop a method of operation that can deal with direct to instructions when the aircraft has passed the freeze horizon of the pre-planner, for example by generating a PTA update.

Table 3: Relationship between time of PTA generation and time of direct to

Test night	**Direct to**	**Relation between time of direct to and time of PTA generation**
23-nov (3 KLM a/c)	ARTIP DENUT	2x direct prior PTA 1x direct after PTA (→ reject)
24-nov (7 KLM a/c)	ARTIP DENUT	3x direct prior, 1x after PTA 2x direct prior, 1x after PTA (→ a/c landed ~3 min before PTA)

25-nov (7 KLM a/c)	ARTIP DENUT	6x direct after PTA 1x direct after PTA (→reject)
26-nov (7 KLM a/c)	ARTIP DENUT	5x direct after PTA 2x direct prior PTA

The other reject was given because the aircraft experienced/expected turbulence and though the PTA was equal to the ETA, the flight crew didn't want to apply speed control to make the PTA. Although the PTA was rejected, the aircraft in the end landed only 17 seconds after its PTA.

Finally, it is observed that (see Figure 4) in 56% of the cases the PTA that was sent to the aircraft was equal to the ETA as calculated on-board the aircraft. So, about half of the flights were not involved in a planning conflict and half of the flights were involved. In particular the traffic flow during the third test night was already well sequenced. It was the busiest night (21 flights), but only 6 flights were involved in a planning conflict.
For the other nights, the flights with a PTA equal to their ETA and not equal to their ETA were more or less evenly distributed.

4.4.2 Test night of 23 November

The test night of 23 November was characterized by a large number of flights that didn't provide an ETA to the pre-planner (7 out of 15). Main factors were the KLM B747-400 and two other flights (ABR4SM and CSN451) that were not known by the pre-planner (i.e. pop-up traffic).

The flight crew of the KLM B747-400 had to manually send an ETA and this ETA was only forwarded to the pre-planner if it differed more than 3 minutes from a preceding system-generated ETA. After this night KLM further refined its procedure for the B747-400 fleet.

It was known and accepted on beforehand that the ABR flight (ATR 72) from the South would have to be treated as pop-up traffic. The CSN flight was not expected in the test period, it was not included in the CIFLO list and therefore not co-ordinated with MUAC. It however arrived early, but could be nicely sequenced without other traffic in close proximity and landed shortly before 5 o'clock UTC (06:00 local time).

During this night two bunches were detected by the pre-planner, see Table 4 and Table 5.

Table 4: First bunch detected on 23 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
DAL70	4:18:00	4:17:30	-30	0:59:31	SUG3B	4:15:44
DAL252	4:20:00	4:20:00	0	1:00:01	SUG3B	4:17:38
MPH072	4:20:00	4:22:30	150	1:00:01	SUG3B	4:23:25
KLM872	---	---	---	---	ART2C	4:19:37

The first bunch involved two DAL flights from the West and a MPH flight also from the West. Later on, a KLM flight from the East appeared as pop-up traffic. See also Figure 8, Figure 9 and Figure 10.

The pre-planner generated a delta time (the PTA minus the ETA)of minus 30 seconds for the first DAL flight and a time delay of 150 seconds for the MPH flight. When looking at the speed behaviour it can be concluded that all three flights showed behaviour as expected, the DAL70 flew somewhat faster than normal, the DAL252 flew standard speeds and the MPH072 flew slower than normal. However, the two DAL flights crossed the FIR boundary relatively close to each other and on parallel headings. Two factors may have contributed. Firstly, the ETAs of DAL flight are received in minutes and not in seconds, this may introduce a large error in the estimated time interval at the runway threshold. In case of rounding or truncating an error up to one minute can be expected, however, in case one time is rounded and the other truncated an error up to 1.5 minutes would be possible. In the second place, when aircraft are flying a heading the FMS is obviously no longer guiding along its lateral path (LNAV mode or managed mode lateral). Normally, then also the VNAV mode (Boeing) or managed mode vertical & speed (Airbus) is not active, this implies that the aircraft is not actively controlling to an RTA as the RTA function is part of the VNAV mode or managed mode vertical & speed.

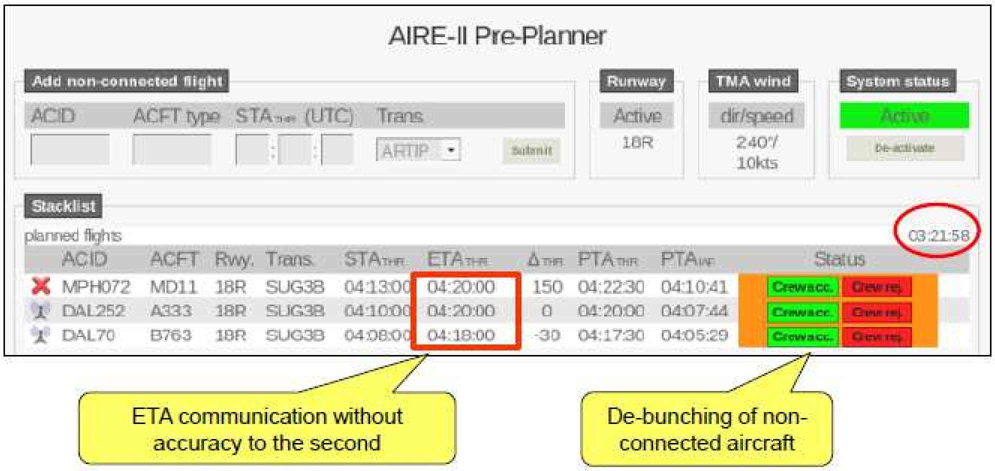


Figure 8: Pre-planner showing first planning conflict on 23 November

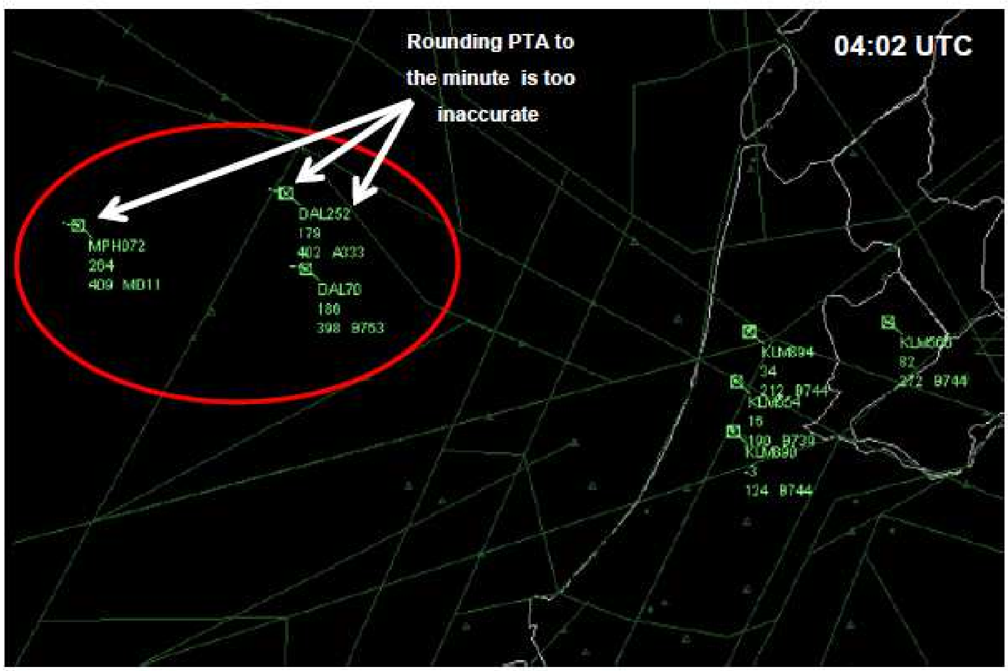


Figure 9: Radar snapshot of aircraft, involved in the first planning conflict, upon FIR entry. The two DAL flights are flying parallel.

To cope with the pop-up traffic from the East (Figure 10), the air traffic controllers decided to sequence the KLM flight between the two DAL flights and the MPH flight. To help the sequencing process, through enlarging the gap, both DAL flights were given a direct NIRSI, thereby shortening their arrival path, and the KLM as well as MPH flight were given speed reductions. As a consequence the DAL flights arrived well ahead of their PTA (about 2 – 2.5 minutes) and the MPH flight arrived one minute later than its PTA.

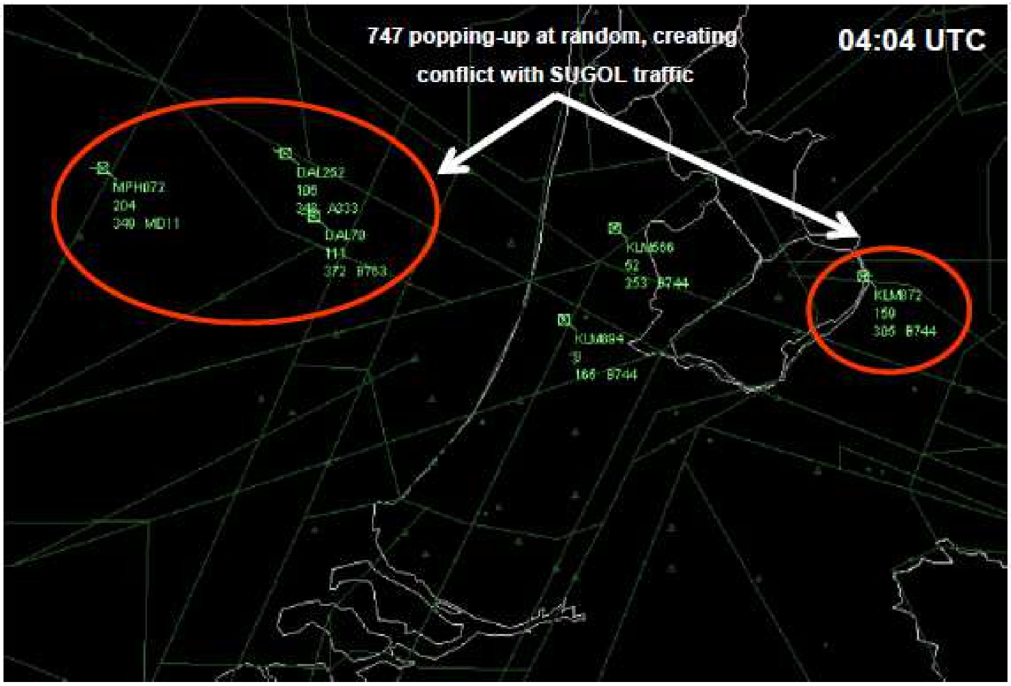


Figure 10: Pop-up traffic during first planning conflict

It is concluded that the gap created by the pre-planning process between the second DAL flight and the MPH flight has prevented a bunch and unintentionally created a gap in which the KLM flight was sequenced.

The second pre-planning conflict that was detected on November 23 involved only two flights, KLM428 and KLM810 both arriving from the East. See Table 5. The aircraft had already well solved their planning conflict prior to the FIR entry, see Figure 12. One of the reasons for the large gap was caused by truncating of the PTA, the PTA (4:40:58) was entered in the FMS as 4:40. The MD11 can only enter an RTA in hours and minutes. As of the second test night the pre-planner did send the appropriately rounded value of the PTA based on the knowledge of RTA entry formats of different aircraft types (i.e. A330 to the second, B777 to the tenth of a minute and MD11 to the minute).

In summary, the first test night did effectively solve the two planning conflicts, but also revealed some issues with the data communication between the pre-planner and KLM 747s.

This night also showed the importance of involving all aircraft in the pre-planning. The pop-up traffic during the first planning conflict could be adequately dealt with, the moment of pop-up was reasonably lucky as it didn't heavily interfere with the pre-planned sequence.

Table 5: Second bunch detected on 23 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
KLM428	4:41:54	4:40:54	-60	1:00:01	ART2C	4:40:16
KLM810	4:42:34	4:43:24	50	1:00:01	ART2C	4:42:58

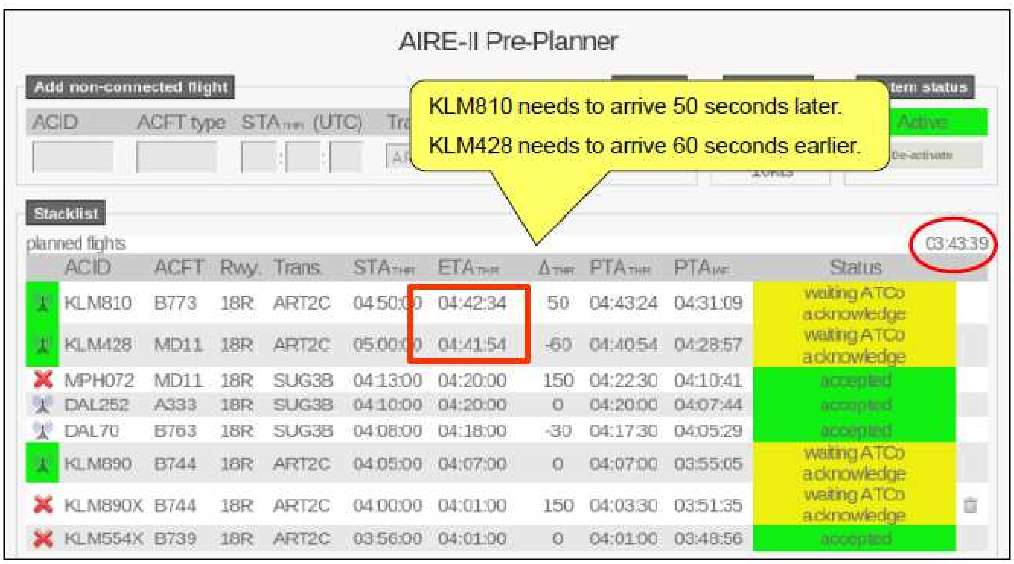


Figure 11: Pre-planner showing second planning conflict on 23 November

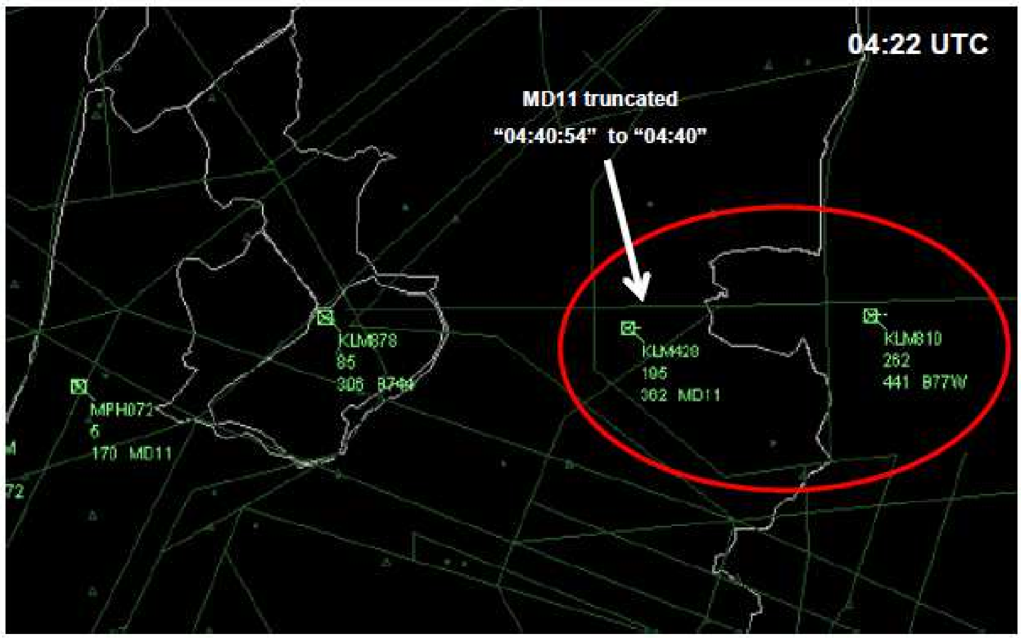


Figure 12: Radar snapshot of aircraft, involved in the second planning conflict, upon FIR entry.

4.4.3 Test night of 24 November

The test night of 24 November was characterized by three planning conflicts that were effectively solved by the pre-planning process. Furthermore, the issue of not receiving ETAs from KLM 747s was partly solved. Two 747 flights did provide an ETA, but 2 others still didn’t. The two flights, of which the ETA wasn’t received, were not involved in or close to a planning conflict. Besides the two 747s one flight (CSN453) popped-up during this night, this flight was not included in the CIFLO list and arrived much earlier than expected. Also this flight didn’t interfere with other traffic, it arrived in between two traffic bunches.

The bunches detected by the pre-planner are shown in Table 6, Table 7 and Table 8.

The first bunch consisted of two flights, DAL70 and MPH084. Due to the fact that the MPH flight was inserted in the pre-planning process through the R/T procedure via MUAC, it was pre-planned much later than the DAL flight. As a consequence, the MPH flight got a delay of 3 minutes. Both aircraft showed speed behaviour that indeed solved the planning conflict. The early landing of DAL70 (one minute ahead of the PTA) was caused by the direct NIRSI (shortcut) given by area control. The MPH flight very well controlled to its PTA, despite the limited time available to do so.

Table 6: First bunch detected on 24 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
DAL70	3:59:30	3:59:30	0	1:00:01	SUG3B	3:58:37
MPH084	3:59:00	4:02:00	180	0:36:40	ART2C	4:01:51

The second bunch of the night of 24 November consisted of four flights, all arriving from the East. Initially, the detected bunch consisted of two flights (#2, #3), these flights were sequenced by speeding up flight #2 (ΔT of minus 60 seconds) and delaying flight #3 (ΔT of 79 seconds). Both flights showed speed behaviour consistent with their PTA. Somewhat later flights #1 and #4 were inserted in the pre-planner after co-ordination with MUAC. Flight #1 had to arrive slightly early and flight #4 got a serious delay (almost 4 minutes). Flight #1 initially flew a standard Mach number, but speeded up during the descent. Area Control applied positive speed control and slightly increased the descent speed. Despite the speed increase this flight landed late, approx 1.5 minutes behind its PTA. Factors may have been rounding/truncating of both ETA and PTA due to the voice communication, and differences in on-board wind predictions and actual descent winds. Nevertheless, the sequence of the first three flights looked good. The planning conflict was effectively solved by the aircraft. It is noteworthy that Area Control generally applied positive speed control.

Flight #4 had to delay almost four minutes. Despite it strongly reduced speed the 4 minutes delay was too much given the limited time to fly, see Figure 13. Area Control had to intervene and gave this flight radar vectors.

Table 7: Second bunch detected on 24 November

Flight ID	**ETA (hh:mm:ss)**	**PTA (hh:mm;ss)**	**ΔT (s)**	**Time to go when PTA was generated (hh:mm:ss)**	**Transition**	**ATA (hh:mm:ss)**
KLM554	4:12:00	4:11:19	-41	0:35:33	ART2C	4:12:43
KLM810	4:14:49	4:13:49	-60	1:00:00	ART2C	4:14:24
KLM566	4:15:00	4:16:19	79	1:00:00	ART2C	4:16:48
BCS6350	4:15:00	4:18:49	229	0:38:20	ART2C	4:19:11

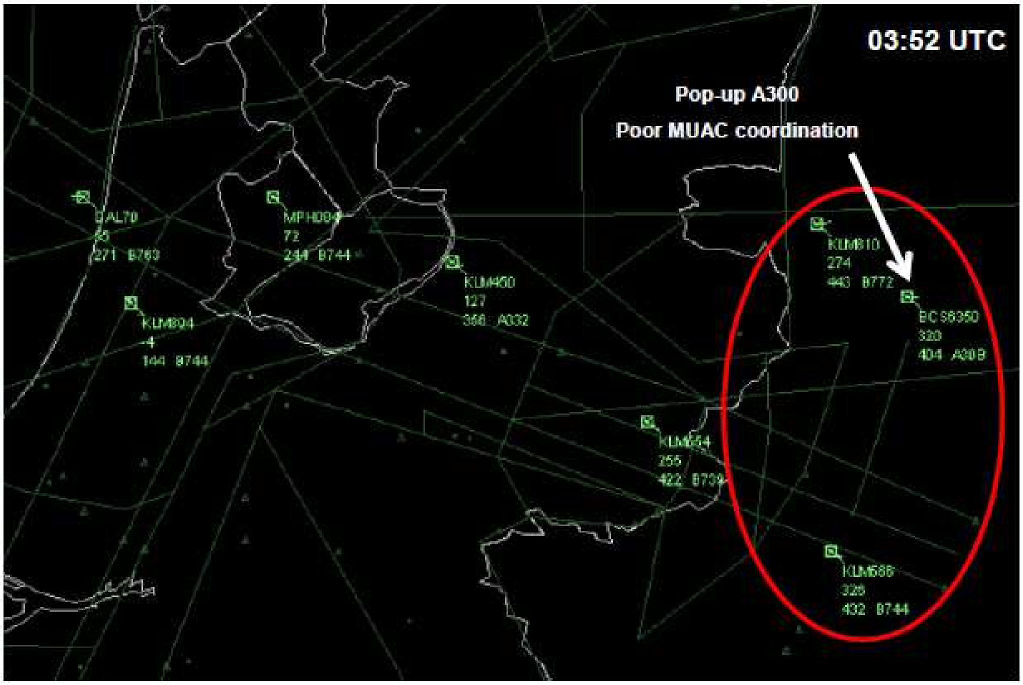
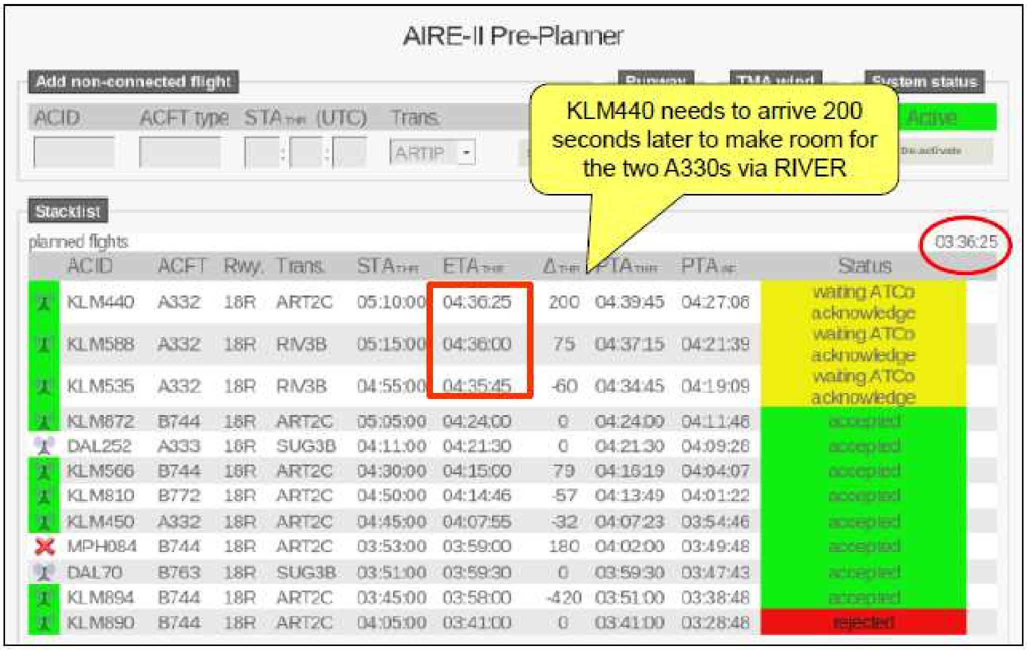


Figure 13: Radar snapshot of the second bunch of 24 November

The third planning conflict on 24 November consisted of 3 aircraft. A fourth flight (KLM447) was just kept outside this planning conflict due to its PTA. See Table 8 and Figure 14.

Table 8: Third bunch detected on 24 November

Flight ID	**ETA (hh:mm:ss)**	**PTA (hh:mm;ss)**	**ΔT (s)**	**Time to go when PTA was generated (hh:mm:ss)**	**Transition**	**ATA (hh:mm:ss)**
KLM535	4:35:45	4:34:45	-60	1:00:00	RIV3B	4:34:48
KLM588	4:36:00	4:37:15	75	0:59:42	RIV3B	4:37:14
KLM440	4:36:25	4:39:45	200	1:00:00	ART2C	4:41:12
KLM447	*4:42:17*	*4:42:17*	*0*	*1:00:00*	*ART2C*	*4:43:21*



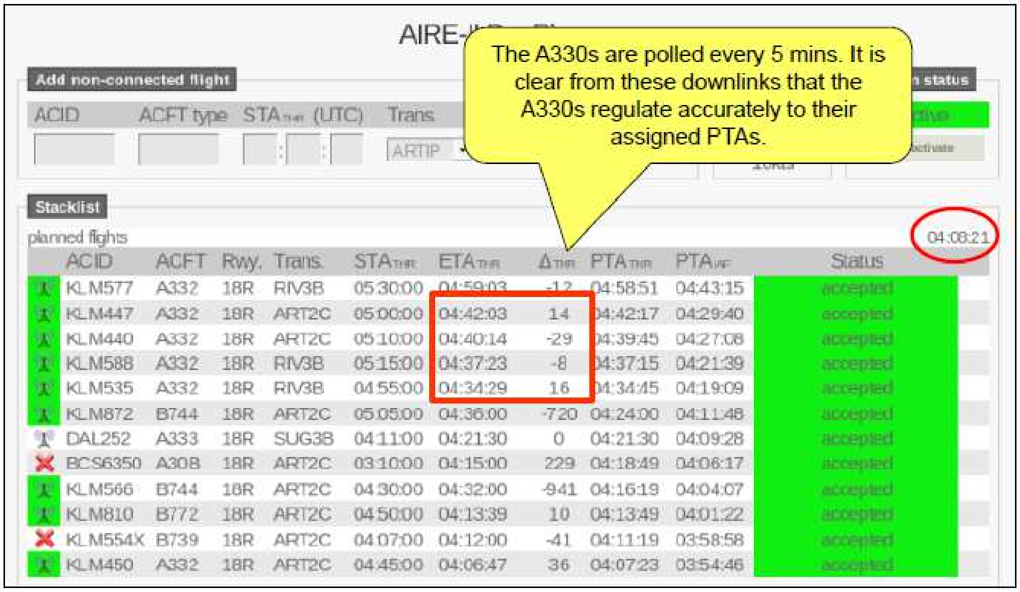
	ACID	ACFT	Rwy.	Trans.	STA THR	ETA THR	Δ THR	PTA THR	PTA IAF	Status
	KLM440	A332	18R	ART2C	05:10:00	04:36:25	200	04:39:45	04:27:06	waiting ATCo acknowledge
	KLM588	A332	18R	RIV3B	05:15:00	04:36:00	75	04:37:15	04:21:39	waiting ATCo acknowledge
	KLM535	A332	18R	RIV3B	04:55:00	04:35:45	-60	04:34:45	04:19:09	waiting ATCo acknowledge
	KLM672	B744	18R	ART2C	05:05:00	04:24:00	0	04:24:00	04:11:46	accepted
	DAL252	A333	18R	SUG3B	04:11:00	04:21:30	0	04:21:30	04:09:26	accepted
	KLM566	B744	18R	ART2C	04:30:00	04:15:00	79	04:16:19	04:04:07	accepted
	KLM810	B772	18R	ART2C	04:50:00	04:14:46	-57	04:13:49	04:01:22	accepted
	KLM450	A332	18R	ART2C	04:45:00	04:07:55	-32	04:07:23	03:54:46	accepted
	MPH084	B744	18R	ART2C	03:53:00	03:59:00	180	04:02:00	03:49:48	accepted
	DAL70	B763	18R	SUG3B	03:51:00	03:59:30	0	03:59:30	03:47:43	accepted
	KLM894	B744	18R	ART2C	03:45:00	03:58:00	-420	03:51:00	03:38:48	accepted
	KLM890	B744	18R	ART2C	04:05:00	03:41:00	0	03:41:00	03:28:48	rejected

Figure 14: Pre-planner showing third planning conflict on 24 November

Flight #1, KLM535 arriving from the South, had to arrive one minute earlier than estimated. This was very well achieved by the aircraft by increasing its speed; a direct RIVER (slight path shortening) also helped. Flight #2, KLM588, also arriving from the South had a delay of 75 seconds. This delay was achieved during the cruise phase, and despite a direct RIVER (path shortening) this flight arrived almost exactly at its PTA. The third flight of this bunch, KLM440, came from the East and got a PTA more than 3 minutes later than its estimated time of arrival. This flight strongly reduced its speed to make the PTA. Area Control applied positive speed control, they slightly increased the descent speed due to flight #4 that also arrived from the East just behind the KLM440. ACC also applied positive speed control to flight #4. This bunch was very well prevented by the pre-planning process. A natural behaviour of the ACC controller also became apparent during this sequence of arriving aircraft: they applied slight, positive speed control.

The progress of the third planning conflict is nicely illustrated in Figure 15 to Figure 18.

In summary, the pre-planning successfully prevented the occurrence of three bunches. In general, the aircraft worked very well towards their PTA despite the sometimes late issuance of the PTA (35 to 40 minutes flying time to go). The pre-planning process also helped for the flight which required radar vectoring, in the sense that a part of the delay was already absorbed by the aircraft itself; therefore the amount of radar vectoring was reduced. This night definitively proved that the concept works.



ACID	ACFT	Rwy.	Trans.	STA_{THR}	ETA_{THR}	Δ_{THR}	PTA_{THR}	PTA_{IAF}	Status
KLM577	A332	18R	RIV3B	05:30:00	04:59:03	-12	04:58:51	04:43:15	accepted
KLM447	A332	18R	ART2C	05:00:00	04:42:03	14	04:42:17	04:29:40	accepted
KLM440	A332	18R	ART2C	05:10:00	04:40:14	-29	04:39:45	04:27:08	accepted
KLM588	A332	18R	RIV3B	05:15:00	04:37:23	-8	04:37:15	04:21:39	accepted
KLM535	A332	18R	RIV3B	04:55:00	04:34:29	16	04:34:45	04:19:09	accepted
KLM872	B744	18R	ART2C	05:05:00	04:36:00	-720	04:24:00	04:11:48	accepted
DAL252	A333	18R	SUG3B	04:11:00	04:21:30	0	04:21:30	04:09:28	accepted
BCS6350	A30B	18R	ART2C	03:10:00	04:15:00	229	04:18:49	04:06:17	accepted
KLM566	B744	18R	ART2C	04:30:00	04:32:00	-941	04:16:19	04:04:07	accepted
KLM810	B772	18R	ART2C	04:50:00	04:13:39	10	04:13:49	04:01:22	accepted
KLM554X	B739	18R	ART2C	04:07:00	04:12:00	-41	04:11:19	03:58:58	accepted
KLM450	A332	18R	ART2C	04:45:00	04:06:47	36	04:07:23	03:54:46	accepted

Figure 15: Progress monitoring of the third planning conflict at 04:08 UTC

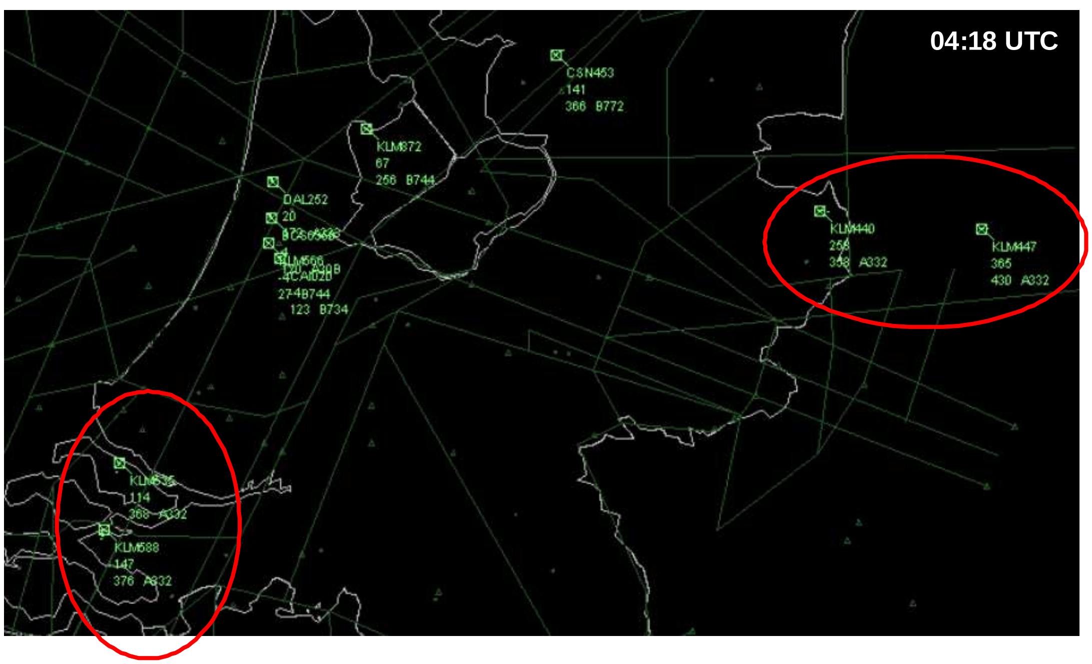


Figure 16: Radar snapshot of the third planning conflict at 04:18 UTC

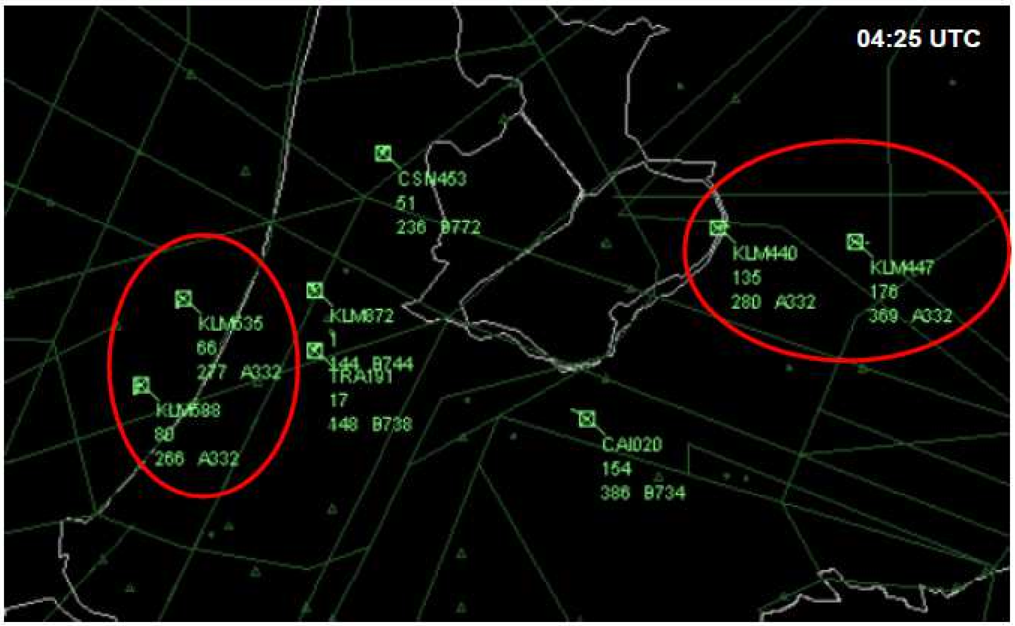


Figure 17: Radar snapshot of the third planning conflict at 04:25 UTC

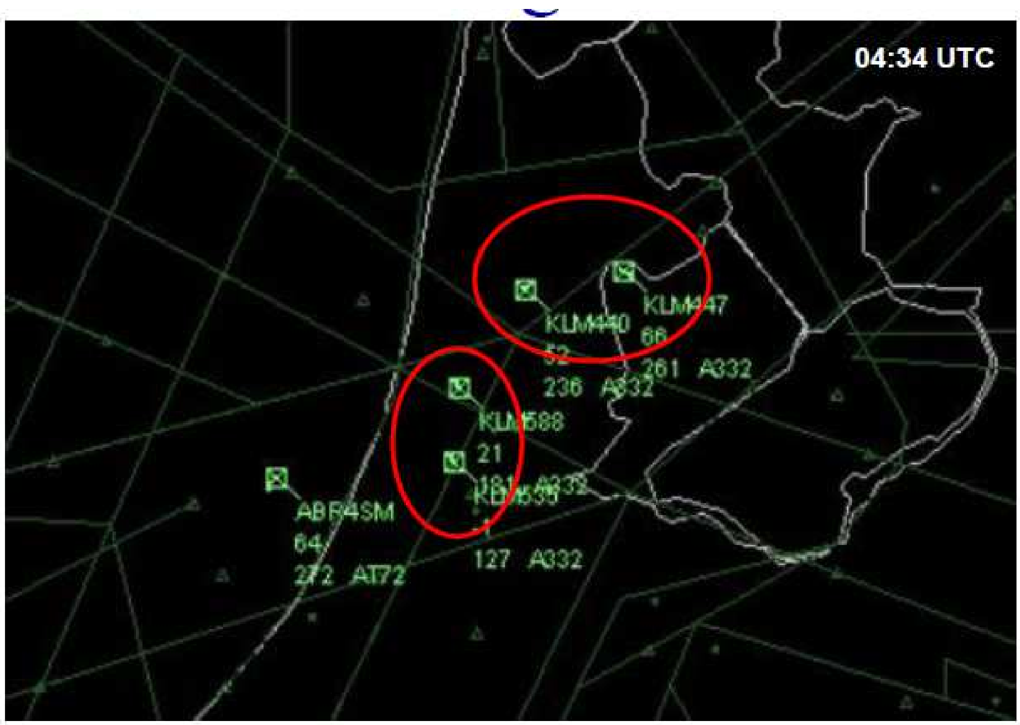


Figure 18: Radar snapshot of the third planning conflict at 04:34 UTC, with flight #1 and #2 on final approach.

4.4.4 Test night of 25 November

The test night of 25 November was characterized by many inbound flights during the test period (21), two actual planning conflicts and three pop-up flights. One pop-up flight interfered with a traffic bunch. The pop-up flights consisted of two KLM 747s and the ABR flight arriving from the South.

The bunches detected by the pre-planner are shown in Table 9 to Table 12

The first 'bunch' consisted of two flights, BCS6350 and KLM890. It became apparent that the ETA of the BCS flight had a gross error. The BCS arrived well ahead of the KLM flight. The voice communication procedure is error prone. Both flights flew an undisturbed descent and approach.

Table 9: First bunch detected on 25 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
KLM890	3:19:00	3:19:00	0	0:55:41	ART2C	3:14
BCS6350	3:19:00	3:21:30	150	0:40:10	ART2C	3:20

The second 'bunch' also consisted of two flights, KLM894 and KLM554. The KLM554 was a Boeing 737-900 and was not connected with the pre-planner via data communication, therefore the voice procedure (LNVL – MUAC – flight crew) to request its ETA and to provide its PTA had to be applied. It became clear that the ETA of KLM554 was incorrect, it was established that the ETA of the Initial Approach Fix (ARTIP) instead of the landing runway was communicated. Consequently, no bunch was present and the aircraft could fly their descents as planned. Again, this proves that the voice communication procedure is error prone and should therefore be improved.

Table 10: Second bunch detected on 25 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
KLM894	3:27:00	3:27:00	0	1:00:01	ART2C	3:26
KLM554	3:29:00	3:29:30	30	0:21:31	ART2C	3:42:47

The third bunch detected by the pre-planner consisted of two closely separated bunches, see Table 11 and Figure 19. By applying the pre-planning process interference between these two planning conflicts have been prevented. This is also a positive effect of the pre-planning process. As can be seen in Table 11 KLM445 and KLM440 controlled very well to their PTA and consequently arrive very well sequenced. Also for these flights slight, positive speed control was applied by LNVL Area Control.

Both DAL flight were transferred from London to Amsterdam ACC on a heading. As mentioned for 23 November this is a potential cause for not controlling towards an RTA. This is confirmed by the speeds flown by DAL70, it flew slowly despite the 30 seconds it had to gain. The LVNL controllers gave both DAL flights a direct NIRSI (path shortening) in order to create a larger gap with the flights coming from the East, and in particular with KLM445. The KLM flight had strongly reduced speed as could be expected, it was successfully controlling to its PTA.
Also the last two aircraft of this bunch (KLM440, CSN451) also showed very good behaviour in making their PTA. In particular the CSN451 was able to loose approximately 4 minutes during the descent. This was overall a very successful de-bunching involving five aircraft and it showed the potential of the pre-planning process.

An item worth mentioning is the sequence of two aircraft from the West (SUGOL) followed by three aircraft from the East (ARTIP). When looking at the ETA of the second DAL flight and the first KLM flight it is mere luck that this sequence evolved. Only a one second difference existed between the ETAs. As the pre-planner worked on a first come, first serviced principle the one second difference determined the sequence. The controller noted that a sequence with a couple of aircraft from one direction followed by a couple of aircraft from another direction is in principle preferred. Therefore, if the difference would have been one second in favour of the KLM flight then the pre-planner should have been more flexible; the controller should have the possibility to adapt the sequence in the pre-planner.

Table 11: Third bunch detected on 25 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
DAL70	4:15:00	4:14:30	-30	1:00:00	SUG3B	4:13:42
DAL252	4:17:00	4:17:00	0	1:00:00	SUG3B	4:15:36
KLM445	4:17:01	4:19:30	149	1:00:00	ART2C	4:19:41
KLM440	*4:22:19*	*4:22:19*	*0*	*1:00:00*	*ART2C*	*4:22:19*
CSN451	*4:21:00*	*4:24:49*	*229*	*0:36:34*	*ART2C*	*4:25:30*

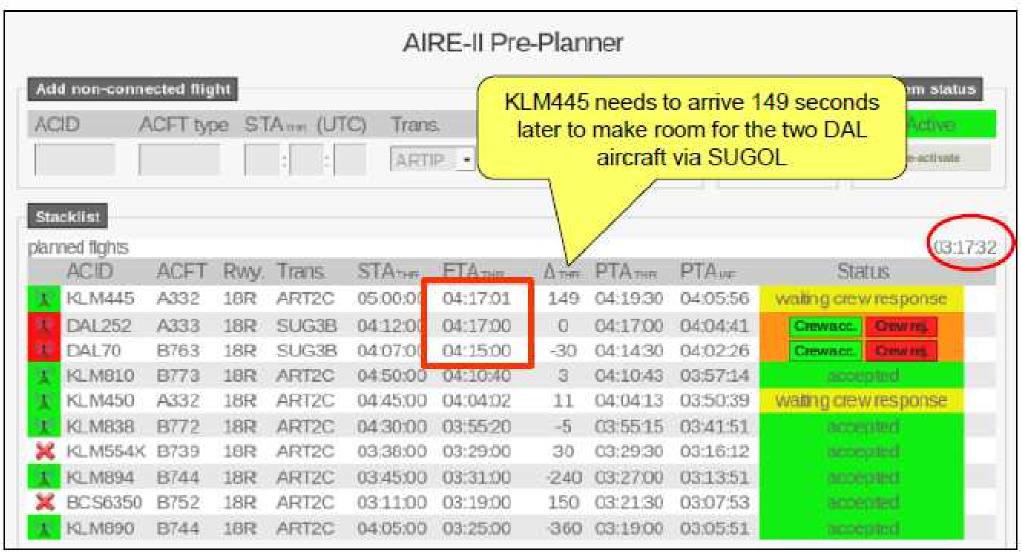


Figure 19: Pre-planner showing third planning conflict on 25 November

Figure 20: Progress monitoring of the third planning conflict at 03:32 UTC

The fourth bunch consisted of two flights, with two other flights in close proximity, see Figure 21 and Table 12. The KLM588 was pre-planned just in front of the KLM872, but arrived much earlier due to two direct to instructions (direct DENUT and later on direct RIVER). The ABR flight was pop-up traffic. This flight was vectored around the other traffic and was sequenced behind this traffic bunch.

Approach control decided to change the pre-planned sequence (KLM872 followed by DAL258) and to adhere to the sequence (DAL258 followed by KLM872) proposed by the operational Inbound Planner system (IBP). The IBP generated a different sequence because it rather quickly plans flights from the East via the longer ART3B transition instead of the much shorter ART2C transition (= standard transition of the pre-planner for flights from the East). Furthermore, it is easier to adapt the spacing between aircraft by giving traffic from the West a direct NIRSI (path shortening) at an appropriate moment. Therefore, it is more convenient to have the traffic from the West at a position in the sequence where path shortening can be used to control the spacing. The result was that the DAL flight was given a direct NIRSI and was kept high on speed, and the KLM flight was given a speed reduction. The DAL flight landed a couple of minutes ahead of its PTA and the KLM flight finally landed approx 1.5 minutes behind its PTA.

Most likely the pre-planned sequence would have worked, but the relatively high speed of the DAL flight at FIR entry was not reassuring. It was questioned whether the DAL flight was controlling to its PTA, and this couldn't be checked via the pre-planner because the flights of Delta (and all other airlines except KLM) didn't automatically provide regular ETA updates to the pre-planner. In the end the behaviour of the DAL flight didn't create an obvious sequence when the aircraft entered the Amsterdam FIR. The pre-planning process didn't fully work for this bunch.

Table 12: Fourth bunch detected on 25 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
KLM588	*4:52:16*	*4:52:16*	*0*	*1:00:00*	*RIV3B*	*4:49:11*
KLM872	4:55:00	4:55:00	0	1:00:00	ART2C	4:56:37
DAL258	4:56:00	4:57:30	90	1:00:00	SUG3B	4:53:06
ABR4SM					*RIV3B*	*4:59:36*

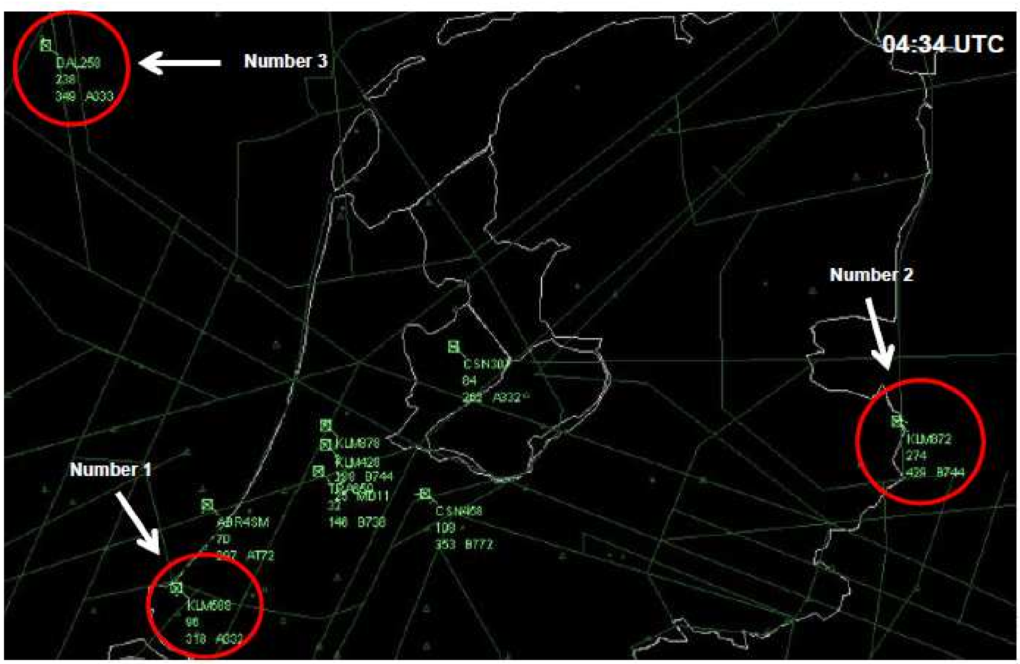


Figure 21: Radar snapshot of the fourth planning conflict at 04:34 UTC

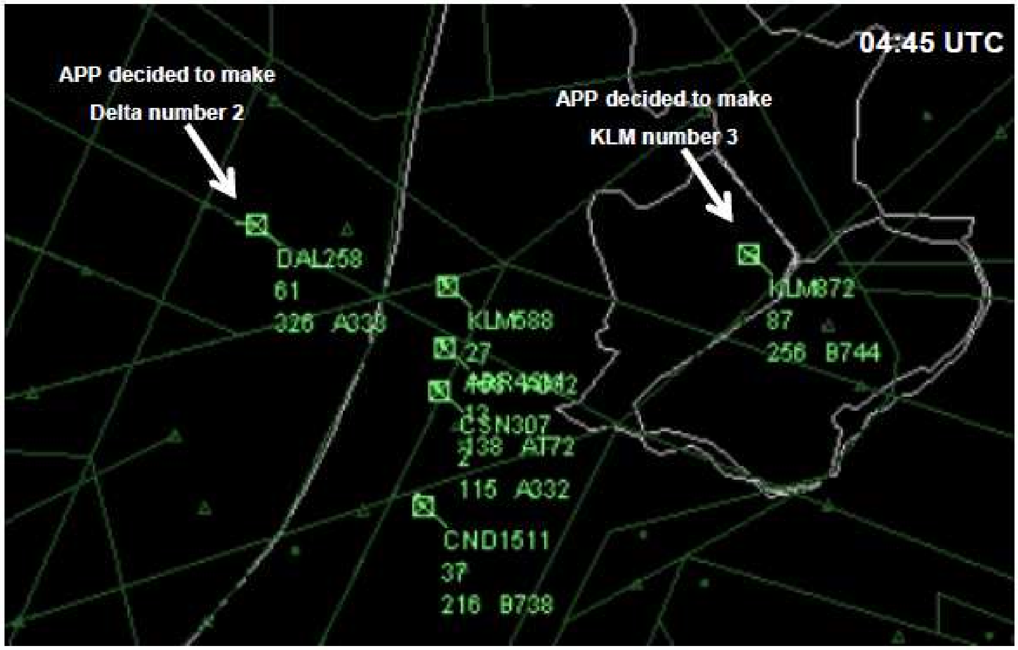


Figure 22: Radar snapshot of the fourth planning conflict at 04:45 UTC

4.4.5 Test night of 26 November

The test night of 26 November was characterized by a huge traffic bunch. Two planning conflicts very close to each other were detected and a CSN flight (co-ordinated via MUAC through the voice procedure) provided an ETA in between the two planning conflicts. However, there was not a large enough gap between the two planning conflicts to schedule the CSN flight in between, consequently the CSN flight got a delay of 12 minutes!
Furthermore, one pop-up traffic (KLM B747) appeared in the middle of the second planning conflict. The reason that this flight popped up is the same as for the preceding test nights.

The bunches detected by the pre-planner are shown in Table 13 and Table 14.

The first bunch consisted of three flights and one flight (KLM810) just preceding the planning conflict, see Table 13 and Figure 23.
The KLM810 nicely controlled to its PTA and consequently did not become involved in the traffic bunch. This can be considered as a positive contribution of the pre-planning process.
The first bunch showed an interesting behaviour on how air traffic control deals with bunches. The pre-planner proposed a sequence starting with an aircraft from the East, followed by one from the West and ending with one from the East again. The controllers felt more confident with a sequence starting with the flight from the West, followed by two flights from the East. The flight from the West can be rather easily influenced by giving a short-cut via NIRSI at the appropriate moment, with this techniques it can be sequenced closely behind the KLM810 flying just ahead of this bunch and (well) ahead of the flights from the East. Furthermore, the two flights from the East can already in an early stage be influenced, in order to properly space these flights, as they are arriving from the same direction. The only difficulty is then to sequence these two flights behind the DAL flight from the West. As a consequence of the controller decision to alter the sequence the aircraft were given a short-cut (the DAL flight) and speed instructions. It is concluded that the confidence in the pre-planner is insufficient to apply random sequences. The pre-planner should be improved to more closely match the current working method or it should enable the controllers to adapt the sequence in the pre-planner. At least, as a first step until controller confidence is built.

Table 13: First bunch detected on 26 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
KLM810	*4:27:31*	*4:27:31*	*0*	*1:00:00*	*ART2C*	*4:27:48*
KLM428	4:30:06	4:30:06	0	1:00:00	ART2C	4:33:39
DAL258	4:32:30	4:32:36	6	1:00:00	SUG3B	4:30:13
KLM440	4:34:26	4:35:06	40	1:00:00	ART2C	4:36:19

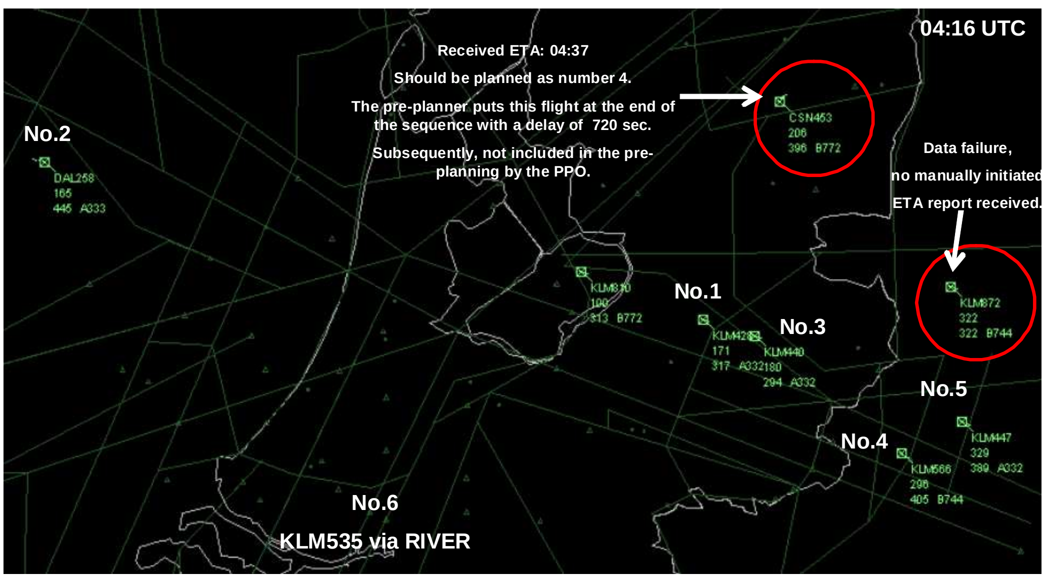


Figure 23: Radar snapshot of the first (No.1, 2, 3) and second (No.4, 5, 6) bunch on November 26

The second bunch consisted of five flights and one pop-up flight (KLM872), see Table 14 and also Figure 23.

Four of the five flights were pre-planned an hour before their estimated landing time. The pre-planner advanced the first flight (KLM566) of these four by one minute and the others got delays up to 150 seconds. The consequence of the PTA generated for KLM566 (4:39:00) , the PTA of the last flight of bunch #1 (4:35:06) and the absence, at least in the pre-planner,

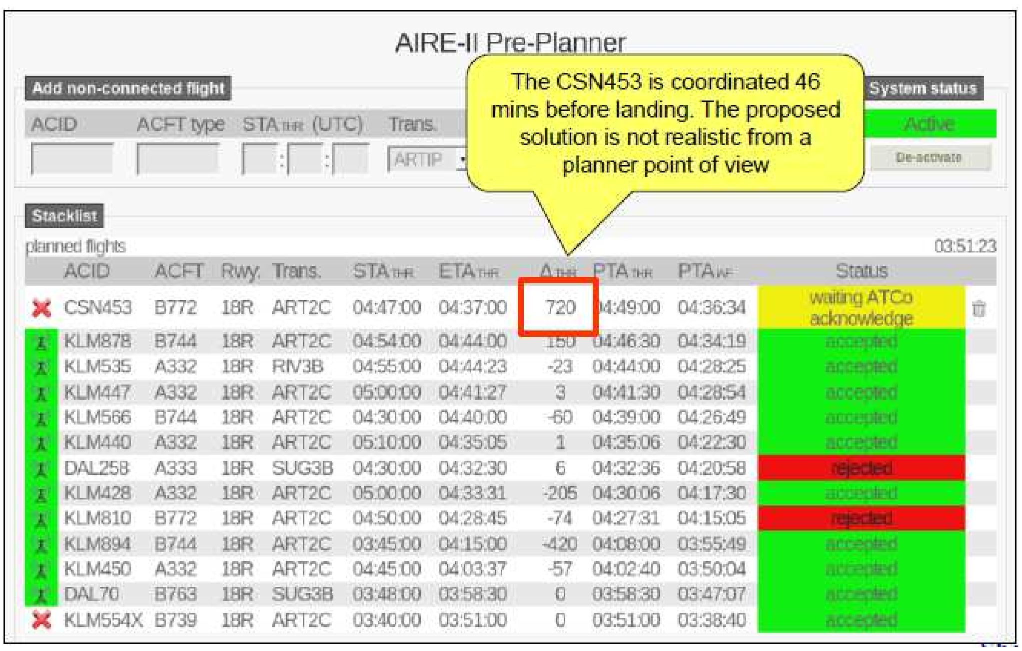
of knowledge about the CSN flight resulted in a gap of approx 4 minutes between the two bunches.
Later on, the ETA of the CSN flight became available and this ETA (4:37:00) fell in the middle of this gap. However, as the landing interval was set at 2.5 minutes the CSN flight couldn't be sequenced in between and consequently was pre-planned at the end of the second bunch, i.e. it got a delay of 12 minutes with less than 45 minutes to fly. The controllers decided to solve this situation tactically, and to sequence the CSN flight directly behind the first bunch, followed by four KLM flight from the East and finally the KLM flight from the South was put behind the queue from the East.
Another complicating factor was the pop-up of a KLM 747 (see KLM872 in Figure 23) in the middle of the second bunch. Its ETA of 04:53 UTC was received near the Amsterdam FIR boundary. As can be seen in this ETA was incorrect, it should have been more in line with the ETA of KLM447 (initially 04:41 and landing at 04:45). Also the KLM872 was tactically inserted in the queue from the East. As a consequence of the 'normal' tactical method of operation some heavy vectoring and even holdings had to be applied.

So, also in this second bunch of November 26 the pre-planning process didn't help the controllers in solving the pre-planning conflict. The pre-planner lacked the flexibility to adapt the sequence as desired by the controllers. Furthermore, this second bunch showed the disadvantage of receiving ETAs at significant different time horizons.

Overall, this test night clearly demonstrated the limitations of the chosen implementation of the pre-planning process. It is concluded that the pre-planning process should be adapted to include all flights at a time horizon of approx 60 minutes (in general this value worked well), either a reliable ETA should be available or, in case the ETA is not yet known, the relative position should be known in order to establish a good sequence at an early stage. The issues of ETA receipt at non-synchronized times and of pop-up traffic shall be resolved. Furthermore, another conclusion is that the controller should have the possibility to adapt the sequence in the pre-planner to bring it more in line with their working methods (grouping together flights arriving from the same direction). An open issue is how to treat in the pre-planning process traffic arriving from the West, when these flights are part of a traffic bunch (tactical) short-cuts are regularly given to neatly space them behind or in front of flights arriving from different directions.

Table 14: Second bunch detected on 26 November

Flight ID	ETA (hh:mm:ss)	PTA (hh:mm;ss)	ΔT (s)	Time to go when PTA was generated (hh:mm:ss)	Transition	ATA (hh:mm:ss)
KLM566	4:40:00	4:39:00	-60	1:00:00	ART2C	4:41:45
KLM447	4:41:09	4:41:30	21	1:00:00	ART2C	4:45:37
KLM535	4:43:27	4:44:00	33	0:59:46	RIV3B	4:52:52
KLM878	4:44:00	4:46:30	150	1:00:00	ART2C	4:50:21
CSN453	4:37:00	4:49:00	720	0:46:11	ART2C	4:39:34
KLM872	*4:53:00*	*4:54:35*	*94*	*0:36:59*	*ART2C*	*4:47:00*



4.5 RTA performance

The accuracy of how well an RTA is realized is illustrated in Figure 24. These 19 flights (7x A332, 5x B744, 5x B777 and 2x MD11) have been selected based on two criteria. Firstly, Air Traffic Control did not act on these flights or only applied minimal, positive speed control (e.g. ATC: report speed --> Flight crew: 307 kts --> ATC: speed 300+). Secondly, the PTA was provided to the flight crew via data communication. This last criterion is used because the voice communication procedure was found to be error prone (e.g. gross ETA errors, rounding/truncating of ETA/PTA), therefore an accurate estimate of the time that was actually controlled to couldn't be made. Furthermore, no regular ETA update was received for these flights contrary to many KLM flights, which provided an ETA update every 3 minutes.

As can be seen the A330 and MD11 in general performed very well, the time errors at the runway threshold remained within 16 seconds with exception of two A330 flights. It is worth noting that KLM, currently for their A330 and MD11 fleets, uplinks descent winds just prior to top-of-descent. Figure 25 illustrates the progress of ETA reporting of the A330 flight that arrived 1 second ahead of its PTA.

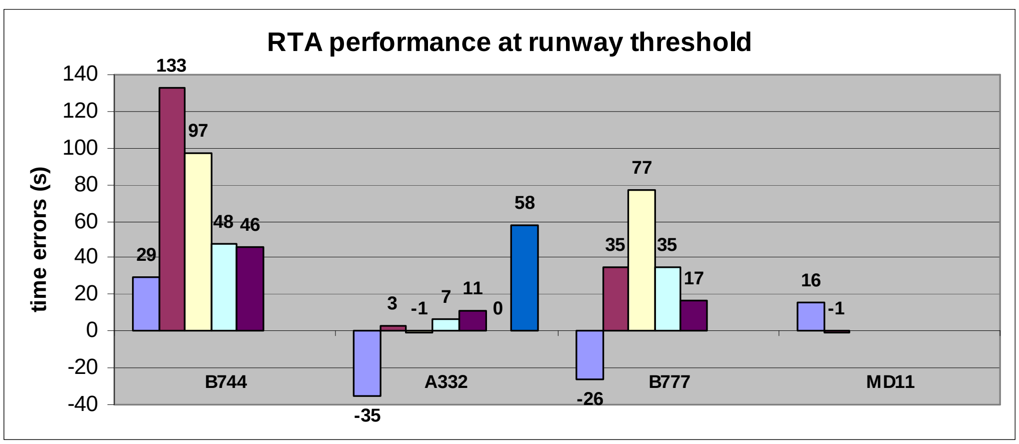


Figure 24: RTA performance for undisturbed or minimally disturbed flights - a positive time error means arriving late.

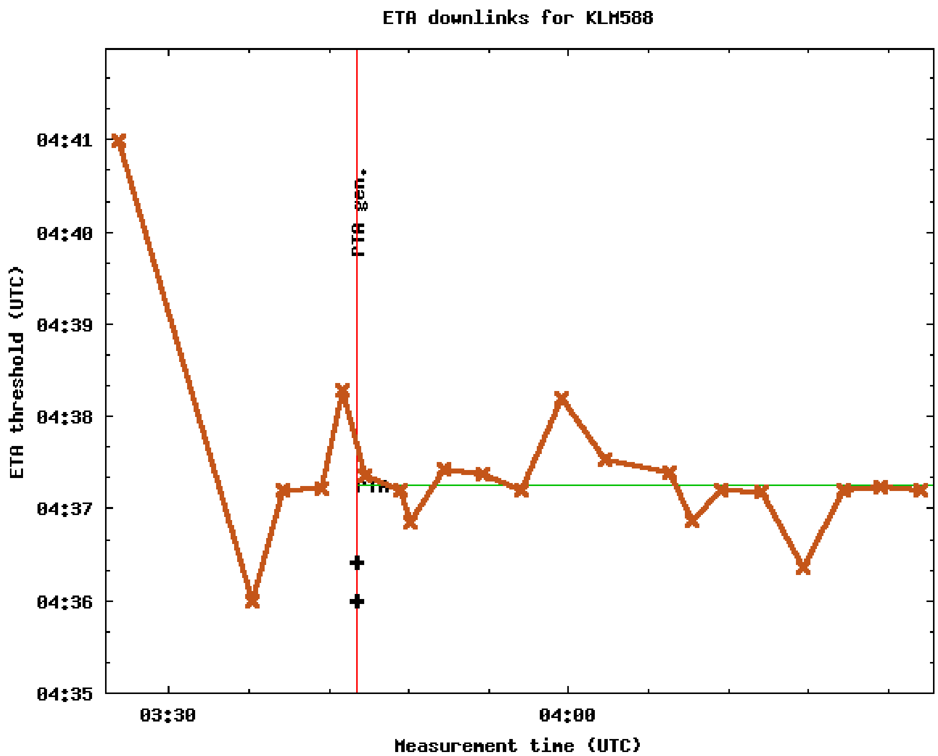


Figure 25: ETA downlinks for KLM588 on November 24.

The flight crew of the A330 flight with a time error of 58 seconds reported that due to the wind they estimated to be 2 minutes late and had to increase speed significantly to correct these 2 minutes. It was also reported by the flight crew that the latest wind update was received 4-5 hours prior to the landing. In the end they were not able to nullify the two minutes. It is concluded that up-to-date, accurate wind (and temperature) information is crucial.

The second A330 flight arrived 35 second early. Figure 26 shows the ETA updates as received during the last 1.5 hour of the flight (landing time was 04:06:48), this shows that the RTA is very actively controlled, initially the aircraft was 20-30 seconds late but during the initial descent the time error changes to 20-30 seconds early. Two factors may have contributed to this behaviour. Flying near maximum speed (M0.84/315) due to a larger than expected head wind may explain the 20-30 kts offset during cruise and incorrect descent winds/temperatures may have caused the time error drop during the initial descent (note that the FMS controls the vertical path during the descent with thrust set at idle, how well the planned speed is flown is in particular a result of the accuracy of the predicted descent winds and temperatures). At approx 20 minutes prior to landing the ETA stabilizes again and since the main part of the last 20 minutes is flown within the TMA (with a number of speed constraints) there is little room to nullify this time error. Another factor may have been that the flight crew manually controlled the time error by using selected speed mode instead of the FMS managed mode.

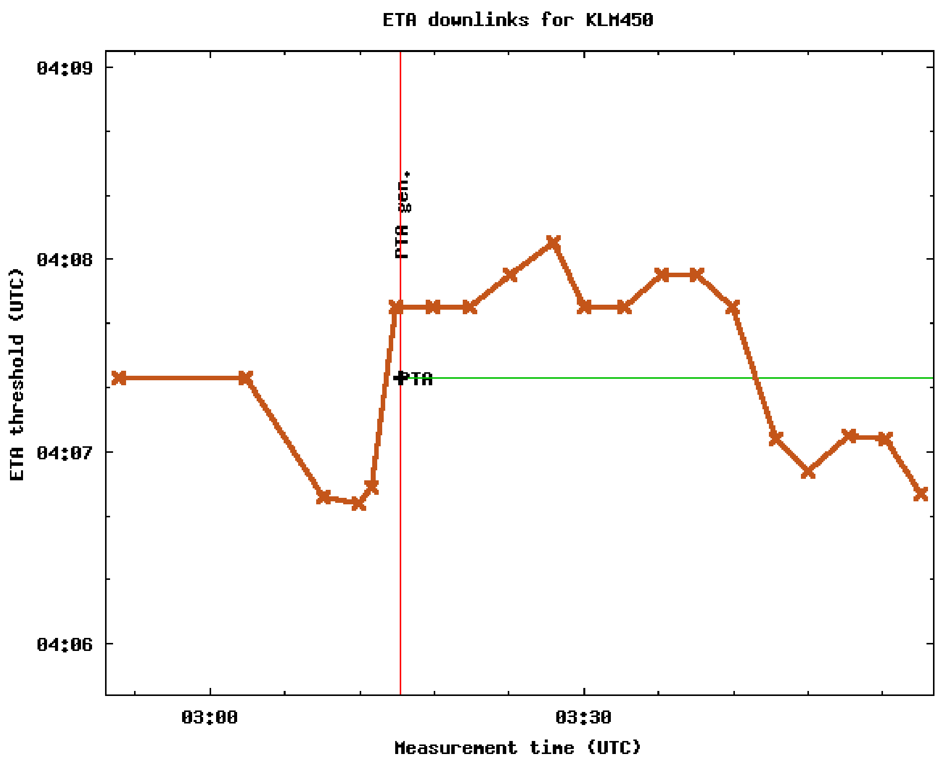


Figure 26: ETA downlinks for KLM450 on November 24.

The RTA performance of the B777, at least during these test nights, was not as good as the A330 and MD11. However, in general still within 35 seconds, with one exception. For this single case (time error of 77 seconds) the pilots reported that the time error was caused by increased descent winds. These incorrect winds were likely to be expected since they also reported that the latest wind update was received and entered in the FMS near the Top of Climb (i.e. approx 1 hour out of the departure airport WSSS – Singapore Changi Airport).

The KLM B747-400 fleet does not have an FMS RTA function, and also no METS service to uplink the latest wind and temperature information prior to top-of-descent. These two factors play an important role in the RTA performance as observed for the KLM B747-400s. The flight crews of the two flights with the largest time error (133 and 97 seconds late, both originated from New Delhi) reported that the latest meteo information had been received approximately one hour after take-off.. It is concluded that meteo information that is many hours old may not be adequate enough to perform time-based operations during the night time at Amsterdam Airport Schiphol. Sometimes it may work well, but sometimes will absolutely influence the RTA performance in a negative way. Clearly time errors of 1.5-2 minutes are not acceptable when landing intervals of 2.5 minutes are used.

4.6 Descent profiles

The impact on the overall descent profiles of flying towards an RTA at the runway threshold has been analysed. Out of the 11 de-conflicted flight pairs that were analyzed, only two trailing flights showed a level segment, three had a reasonable idle descent profile, one didn't have an idle descent profile and the remainder performed good idle descents. The speed efficiency (close to their nominal speed profiles, constant or accelerating or decelerating during the descent) was remarkably good for the trailing aircraft of the de-conflicted pairs, for the leading flights the speed efficiency was much less.
In summary, flights that are successfully de-conflicted often show an efficient descent.

The flight profiles of the flights of the four test nights in November 2011 consisted of 21 fully idle profiles, 20 reasonably idle profiles and 9 non-idle continuous descent profiles. In total 23 of the flights had to level off during the descent, in many cases due to the FL100 constraint at the Initial Approach Fix. Analysis revealed that in particular the correctness of wind and temperature information is key to an efficient time-based operation, but also the uncertainties in the flown routes (i.e. late direct to instructions) do influence the efficiency of the flown descent profiles. Finally, Expected Approach Time shifts (from the operational Inbound Planner System) combined with ETA shifts (from the aircraft) sometimes has a negative impact on the efficiency of the flown descent profiles.

4.7 Environmental benefit indicators

An indication of the yearly environmental benefits is determined based on data of the November trial. The total time the aircraft had to loose or gain is determined for each test night, this is based on the planning conflicts determined by the pre-planner and subsequently the delta time given to individual aircraft. In normal operation (without the pre-planner system), the controller would need to delay a flight until enough separation was created. This is usually done by vectoring, thus adding track miles. Using the pre-planner, this same delay is absorbed linearly by using speed control. We assume that the latter does not increase fuel flow. The difference between current operation and the pre-planning system is depicted in Figure 27.

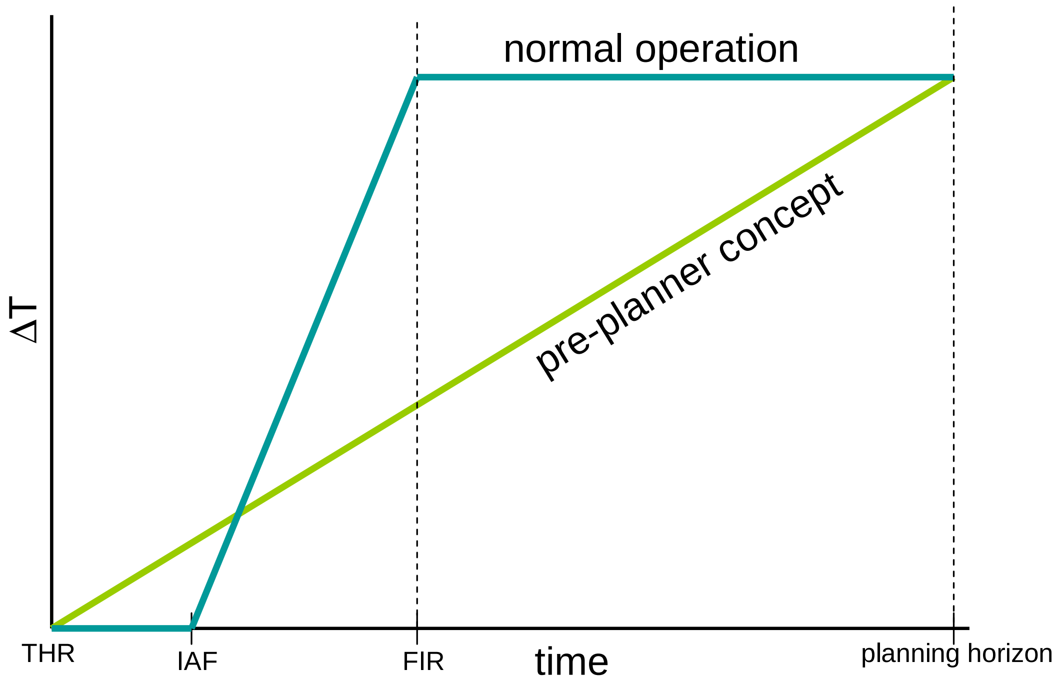


Figure 27: difference in absorbing delay between normal operation and the pre-planning system

Summation of these individual delta times gives the total delta time for a particular night. This total delta time is an indication of the (in)efficiency of the arrival flow. During nights with a low total delta time (e.g. 25 Nov 2011) the traffic demand is well spread and ample opportunities exist to fly undisturbed descents. During nights with a high total delta time the opposite is true.

Table 15 provides an overview of the total delta time for three of the four test nights. The first test night is discarded because of the large amount of traffic not known to the pre-planner. A realistic total delta time could therefore not be calculated for that night.

As expected the night of 24 November can be considered as an average test night regarding bunching. The night of 25 November had some light bunching and the night of 26 November contained some heavy bunching. The total delta time was on average 14.1 minutes per night.

Table 15: Indication of fuel and CO_2 benefits given a successful pre-planning

Night	Total ΔT (sec)	Total ΔT (min)	Total fuel benefit (kg)	Total CO_2 benefit (kg)
24-Nov-12	924	15.4	1480	4670
25-Nov-12	498	8.3	800	2520

26-Nov-12	1124	18.7	1800	5680
average per night	848.7	14.1	1360	4290
365 (average) nights		5163	497110 (497 tonnes)	1565910 (1566 tonnes)

A weighted fuel flow has been estimated given the traffic mix during the November test period and given the fuel flow data (in kg/min) that KLM has provided for their fleet. The basic assumption is that the total delta time in current operation is flown in level flight at FL100 with a speed of 250 KIAS (typical TMA entry conditions for bunches), and with the pre-planning process it is assumed that this delta time is corrected during cruise and descent by speed corrections only (i.e., no fuel penalty). The positive effect on fuel consumption of flying parts of the cruise flight phase and the descent at lower speed (a lower Cost Index closer to the minimum fuel strategy) is not included in this estimate, but on the other hand also the speed instructions (used in combination with radar vectoring) to delay flights in current operations is not included. More importantly, lifting of altitude constraints is also not included in this estimate. Overall it is the project team's opinion that the numbers presented below are conservative.

The weighted fuel flow is determined to be 96.3 kg/min. Given the average delta time of 14.1 minutes, the indicator of fuel benefit for inbound traffic to Schiphol, in the 04:00am to 06:00am (local time) timeframe, is in the order of 1360 kg. And as 1 kg fuel equates to 3.15 kg CO_2, the CO_2 benefit indicator in this timeframe is 4290 kg. On a yearly basis the benefit indicators would cumulate to 0.50 kilo tonnes fuel and 1.57 kilo tonnes CO_2. See also Table 15.

5 Lessons learned and open issues

The nightly Schiphol trials provide valuable lessons for future time based operations and controlled time of arrival procedures for a number of topics. These include concept of operations, information exchange (SWIM), information provision to pilots and ATCo and technical issues. Below these categories are summarized and the lessons learned and open issues are described.

5.1 Concept of Operation

As the content of the trial was unique in a number of ways, the pioneering factor of the concept of operation was relatively high. It has been demonstrated that the pre-planning process works, but also valuable lessons have been gained from the limitations of this process and the chosen implementation. The trial provided a thorough understanding of the challenges of time based operations as foreseen in SESAR step 1.

A number of recommendations and open issues have been identified:

- The pre-planning process should be adapted to include all flights at a time horizon of approx 90 to 60 minutes (in general this timeframe worked well), either a reliable ETA should be available or, in case the ETA is not yet known, the position relative to connected aircraft should be known in order to plan all traffic 60 minutes before landing.
- The controllers should have the possibility to adapt the sequence in the pre-planner to bring it more in line with their working methods (e.g. grouping together flights arriving from the same direction). The same result can be achieved by adding more intelligence to the planning system.
- A more direct involvement of the Approach controllers is needed in the pre-planning process. In the current set-up the pre-planning process was managed by Area Control. This meant that Approach, as the receiving unit, was insufficiently involved in the operational plan that was created 60 minutes prior to landing.
- The direct clearances given to traffic coming from the South (direct DENUT) have challenged the "single shot concept" which formed the basis of the trial. In future testing re-negotiation of the PTA must be possible to accommodate late direct clearances when possible.
- There is a trade-off between flexibility, for example in accommodating direct clearances, and the ability to deal with bunches. Sometimes a bunch or a tight, de-bunched sequence may fully eliminate the advantages of a direct clearance. The time gained by a direct clearance could result in a situation that the aircraft arrives in the middle of a de-bunched sequence and consequently has to absorb a delay, in case this delay cannot be achieved by speed control only then the aircraft may have to be vectored at low altitudes. There is a need for an increase in traffic flow awareness on the flight deck: the system works to optimize to overall traffic flow and not the individual aircraft, i.e. low altitude tactical operations due to last minute changes should be prevented as much as possible. Stable and predictable flows are key.
- A few times aircraft were handed over on a heading, this typically involved two aircraft flying closely together on parallel tracks. Apparently, the pre-planning process didn't in all cases result in a natural and early building of the sequence.

When aircraft fly on a heading it is very uncertain whether they are actively controlling to an RTA as the FMS is not guiding the aircraft (at least not for lateral navigation). It is recommended to inform adjacent sectors of the desired sequence. Thereby these sectors could, if intervention is deemed necessary, influence the traffic in such a way that it helps in building the desired sequence. Furthermore, it is recommended to generate the sequence based on both ETA information and the relative position of flights. The latter could be automated or could be a controller task.

- RTA performance is currently strongly dependent on the aircraft type. Obviously, time based operations benefit from state-of-the-art FMS RTA functions.

5.2 Data exchange

- Aircraft without the capability for data-link were involved in the trial by using voice communication. The procedure to exchange pre-planning information, with the assistance of adjacent centres, was found to be error prone and too laborious, and should not be considered in a pre-implementation concept.
- Connected aircraft (either automatically connected, or web-connected aircraft) must provide accurate ETA within the timeframe of 90 to 60 minutes before landing. In case ETA information is provided earlier, it must be updated within the 90 to 60 minute time horizon).
- For each aircraft type (and even each FMS revision), data exchange may be slightly different; sometimes small changes to the message format need to be made dependent on the aircraft type. This is something that needs to be implemented and tested carefully. It is also error prone as when an aircraft receives an FMS update, it may be that the message exchange process needs to be updated as well.
- For KLM 747 aircraft a special flight-deck procedure was created because these aircraft are not able to completely participate in the data exchange process. This procedure involved some additional actions to be taken by the flight crew. This procedure to exchange ETA information with KLM 747s was found to be cumbersome and not always reliable. Regularly, ETAs were received late (at Amsterdam FIR entry) and these late ETA were sometimes found to be incorrect. The procedure of manually sending an ETA was found acceptable from a cockpit perspective for a short and limited trial, though much effort had to be spent to make it work. This working method needs to be reconsidered in a pre-implementation concept.
- It is strongly recommended to develop and to use system-to-system (FMS to pre-planner) data communication as extensive as possible to avoid time-consuming coordination via R/T and telephone.

- To be able to keep track of ETA progress, regular ETA updates should be available for the controller *after* the aircraft has received its PTA. During the trial, an interval of 5 minutes was used for this purpose (this worked well for the majority of the KLM fleet). Alternatively an ETA update could be send in case the difference between actual and reported ETA exceeds a certain threshold (i.e. event-driven ETA updates).

5.3 Data quality

- The ETA and subsequent RTA performance is highly dependent on the quality of the wind and temperature information used to calculate the ETA. It is strongly recommended to implement the KLM Mets service (or something similar) as extensive as possible, and to make sure that aircraft receive a meteo update prior to the planning horizon of the pre-planner (e.g. 75 minutes prior to landing or on request of the pre-planner).
- Rules should be established for all aircraft types about the resolution of the time information that is exchanged with the pre-planner (seconds, minutes rounded, minutes truncated) to avoid unnecessary error sources.

5.4 Technical experience

- One of the success criteria for the technical platform was the use of existing and proven technology as much as possible. Using a web-browser as interface makes the system easily accessible from any place with an internet connection. The planning system itself uses the middleware and some components of NLR's ATC researsh simulator NARSIM. This obviously saved precious development time.
- The same holds for the data-link part, KLM has extensive experience with ACARS data-exchange with their fleet. This experience turned out to be very useful during the project.

5.5 Involvement and commitment of flight crews and adjacent sectors

- Very careful attention should be paid to inform a large number of flight crews of the purpose of and their involvement in each phase of the trial, and its relation to an overall ATM vision. The communication process is complex, but very important as this buy-in is key to the success of such live trials.
- The importance and difficulty of clear and unambiguous flight crew instructions, that are understandable for everyone involved in the trial (including different aircraft types), was evident.

- The involvement of appropriate operational persons in the project team was very important. Evolving flight crew and aircraft related issues were quickly resolved due to the support and commitment of Flight Operations management.
- To be able to properly evaluate the results it is essential that flight crews are debriefed such that correlations can be found between observed issues and cockpit procedures.
- The cooperation with NATS and MUAC was instrumental to the success of the trials. Though the adjacent centres did not report major issues or peculiarities during the trial, the amount of non-connected aircraft should be kept to a minimum because of the time-consuming coordination between LVNL and adjacent centres.

6 Conclusions and future work

In the Night Time CDA's at Schiphol airport project, the Dutch ANSP LVNL, KLM and Dutch aerospace laboratory NLR have jointly developed and demonstrated a system innovation to introduce time based operations for nightly inbound traffic. In a relatively short period (1.5 years), the team has developed procedures, data-links and a planning system that tries to minimize the amount of intervention necessary for inbound traffic. The system is based on existing technology such that the short development cycle could be realized.
The concept works by communicating to aircraft long before landing (i.e. 60-90 minutes out). When the planning system detects multiple aircraft arriving simultaneously (i.e. a bunch), the aircraft are requested to adapt their time of arrival using the RTA functionality of the board computer. In this early stage, aircraft can influence their time of arrival by minutes simply by applying minor speed control. As a result, aircraft are less likely to be part of a bunch and hence are able to fly an undisturbed CDA.
Obviously the fleet mix is not homogeneous. The project team has put a lot of effort in getting all airlines and all aircraft types involved. For KLM aircraft (which make up around 70% of the total amount of inbound traffic at night) a data-link with the aircraft was created. Other airlines were involved by OCC access to the planning system (Delta) or R/T (other airlines). Cooperation with adjacent centres NATS and MUAC was set-up to ensure proper coordination.
In four phases the system and necessary procedures were iteratively developed and tested. In phase 4B the total system and all procedures were tested during four consecutive full night tests. The results of these four nights form the basis of this report.
From these nights, it can be concluded that the concept worked. With the planning system and within the created procedures including good cooperation with adjacent centres, the team has proven to be able to prevent bunching in the Amsterdam FIR. There is a relation between preventing bunches from occurring and the amount of fuel used in the descent phase. Although no full emission reduction trials have been executed, an educated guess can be given about the amount of CO_2 that can be saved when using the planning system and its procedures. An indication of the fuel benefits is 0.5 kilo tonnes on a yearly basis, this equates to approx 74 kg per flight, which is almost 50% more than the estimate in the project proposal. It should be emphasized that this fuel benefit indicator does not include the benefits of lifting TMA entry restrictions, which was one of the objectives of the fifth phase. The fuel benefits presented in this report can therefore be considered an underestimate compared to the situation in which the whole concept is implemented. Phase 5 was not executed, the main reasons were that the progression of tests towards the end trial took longer than expected (phase 4 consisted of two test periods instead of one) and that the

requirement for an extra (night shift) controller during the test periods limited the amount of tests that could be performed.

In the course of the project, many lessons have been learned. Live trials with RTA time based procedures at this scale are relatively unique. The lessons learned are therefore valuable for future time based operations (i.e., SESAR step 1). Important lessons have to do with procedures (and their workload), coordination with adjacent centres, technical issues and differences between aircraft types. SESAR projects 4.3, 5.6.1, 5.6.4 will benefit from this AIRE-II project as Consortium LVNL is involved in these operational projects. Results have already been presented in 5.6.4 and the material will be made available for projects 4.3 and 5.6.1.

Future work

A next step that can be taken is a pre-implementation trial. This next step is built on the following aspects and assumptions:

1) KLM and Delta airlines have the majority (90% +) of movements in the target test timeframe (the early morning long haul arrivals). SkyTeam therefore has the opportunity and ability to solve the current sub-optimal and bunchy traffic pattern by migrating their night time Schiphol traffic to time-based ops. This transition will enable further optimization of the descent profiles for the benefit of the environment and for fuel savings.
2) The AIRE-2 trial was executed with an extra controller on duty to take care of the pre-planning process. In a pre-implementation trial, a concept needs to be developed, which does not require extra staff on duty. In order to be able execute a trial without additional staff the pre-planning process must be made much easier and simpler. The effort to coordinate planning times with non-connected aircraft must be eliminated.
3) During the AIRE-2 trial much progress has been made to successfully de-bunch inbound traffic. However, in some cases, the pre-planning process was not successful to de-bunch traffic. It was felt that a higher success rate is needed in order to make the process of real value to the controllers. Therefore a number of conceptual and technical changes need to be developed in order to make the pre-planning process more robust (e.g. more flexibility to manually improve the sequence and/or re-planning aircraft after passing the planning horizon). The goal for the pre-implementation phase is to successfully de-bunch more than 90% of all inbound planning conflicts in the target test timeframe.

4) En-route centres are in general concerned about the expanding planning horizons of arrival management systems, extending the planning phase into the en-route domain. The main concerns that en-route centres have are:
   a. how to deal with multiple arrival managers influencing en-route traffic within the same airspace. The concern focuses primarily on the question of how to deal with different or divergent arrival management concepts
   b. downstream sectors communicating clearances/instructions directly to aircraft under their control

   These concerns need to be addressed and procedures need to be developed and tested such that confidence is created with en-route centres that an arrival management concept, with a planning horizon of 60 to 90 minutes could work well within their own ATM concept and will not create extra workload in the en-route sectors.
5) Study of exact influence of the weather updates in the cockpit and how to improve onboard weather information. Note that KLM uses a meteo service that, before passing top of descent, provides descent wind updates to the FMS in order to improve the descent planning and ETA predictions. During the AIRE-II trial this meteo application was available to a part of the KLM fleet. KLM will expand this service for its fleet.

7 List of abbreviations

ACARS	Aircraft Communication and Reporting System
ACC	Area Control Centre
AIRE	Atlantic Interoperability Initiative to Reduce Emissions
ATA	Actual Time of Arrival
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CDA	Continuous Descent Arrival/Approach
CFMU	Central Flow Management Unit
CIFLO	CFMU Human Machine Interface for Flow Management Positions
CTA	Controlled Time of Arrival
ETA	Estimated Time of Arrival
FIR	Flight Information Region
FMS	Flight Management System
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
LT	Local Time
NSA	National Supervisory Authority
OCC	Operations Control Center
OPS	Operations
PPO	Pre Planner Operator
PTA	Planned Time of Arrival
R/T	Radio Telephony
RTA	Required Time of Arrival
SESAR	Single European Sky ATM Research
S-JU	SESAR Joint Undertaking
SUP	Supervisor
SWIM	System Wide Information Management
TBO	Trajectory Based Operations
TOC	Top of Climb
TOD	Top of Descent
UTC	Coordinated Universal Time

Appendix A Information for participating airlines

Right after the first phase of the project, the project team used the traffic analysis to contact all airlines with flights in the pre-planner window. Below the communication information for those airlines is included.

AIRE-2 Trial, Trajectory Based Nighttime CDA's at Schiphol Airport

Information for Participating Airlines

1. Introduction

The SESAR Joint Undertaking (SJU) has a programme in place, in cooperation with the FAA to reduce emissions: AIRE: Atlantic Interoperability Initiative to Reduce Emissions. The SJU has recently contracted the second stage of the AIRE programme. Under this initiative ATM stakeholders work collaboratively to perform integrated flight trials and demonstrations validating solutions for the reduction of CO_2 emissions. Information about the AIRE-2 programme can be found at http://www.sesarju.eu/environment.

One of the flight trials which has been selected by the SJU is the performance of Trajectory Based Night Time CDA's at Schiphol Airport. This trial is developed by KLM, LVNL and NLR. The goal of the trial is to reduce emissions by lifting restrictions, cutting track-miles, and increasing the percentage of top of descent CDA's into Schiphol airport.

2. Project Description

The trial at Schiphol airport revolves around an experimental pre-planning system to optimise the handling of arriving traffic. At Amsterdam Schiphol Airport low altitude CDA's are flown in the final stage of the flight, typically from 4000 – 5000 ft. These so-called transitions have been implemented since the mid 90's for noise reduction purposes. Sequencing traffic on the low-capacity transitions creates inefficiencies in the arrival management process, in particular when traffic comes in bunches. Pre-planning of inbound traffic is expected to alleviate this inherent inefficiency in todays'operations.

The period of application of the pre-planning function is the early morning period typically 04:00 – 06:00 hour landing time. This period is characterized by a "wave" of long haul traffic primarily from the east. In the current situation this “wave” of approximately 15 to 20 aircraft sometimes tends to arrive in bunches which necessitates vectoring (or even holding) to balance capacity and demand. The pre-planning planning system supports the air traffic controller in his/her task to plan inbound traffic streams such that bunching of traffic is avoided.

It is the intention to feed the planning system with down-linked trajectory data from the aircraft that includes Estimated Times of Arrival (ETA) for one or more points on the route. This data is used to make an optimized pre-planning of arriving traffic in the timeframe. The planning will be presented to the ATCOs of ATC the Netherlands. In addition the planning will be shared and coordinated with Maastricht UAC and NATS.

Based on the pre-planner ATC will communicate a planned arrival time to the aircraft via the airline operations function. These arrival times will be kept as close as possible to the downlinked (intended) arrival time, unless planning conflicts occur. The uplinked planned arrival time can either be accepted or rejected by the flight crew. No further negotiation of trajectory information is foreseen in the trial.

ATC the Netherlands will endeavour to provide CDA clearances prior to top-of descent to participating airlines, in coordination with adjacent centres when applicable. Maastricht Upper Area Control (MUAC) will provide assistance to the trial which is especially important in case of handling of non-participating aircraft.

The execution of the trial is scheduled in the October – November 2011 timeframe. For the trial to be successful it is important that all aircraft in the targeted time frame participate.

The following improvements are expected to lead to the expected (fuel and) CO_2 reduction:

- lifting altitude restrictions at Initial Approach Fixes
- CDA clearance prior to Top of Descent
- Track-mile reduction in the Dutch FIR through “direct IAF” routes

3. Participating in the project

Participating airlines will be asked to share FMS calculated ETA information with the ground system. There are three ways in which airlines can participate in these flight trials.

1. Communication of ETA information through (airline-ops) datalink
2. Communication of ETA information through a web-based form
3. Communication of ETA information through radiotelephony

Clearly the first two options have important advantages over the third option. The most important aspect is the timeframe in which the information can be obtained. Option 3 is in fact only available as a viable alternative to options 1 and 2 for aircraft which come from the east via Maastricht airspace to Schiphol. A brief explanation of the options is given below.

Option 1: Communication of ETA information through (airline-ops) datalink

The pre-planning system will communicate using MQ messages. Participating airlines will need to be able to communicate using such MQ messages. The planning system generates MQ messages for the participating flights and expects responses also in the form of MQ messages. It is up to the airlines to communicate these messages to the crews. Within the scope of the flight trials, a number of messages are foreseen. The aircraft/airline should be able to send:

a. About 90 minutes prior to landing, inbound EHAM flights need to send a message to the system to make the system aware of the flight.

And should be able to receive:

b. A “route and ETA” request message from the system that should be followed by a response message that contains the route that is currently active in the FMS. In addition the message should contain an ETA at the runway and/or at the IAF.
c. A “transition” message that contains the active transition. This should be entered in the FMS by the crew in order for the FMS to generate reliable ETAs.
d. A planned arrival time message that contains a “required time of arrival”. The crew should respond with either “accept” or “reject”.

Option 2: Communication of ETA information through a web-based form

The participating airline communicates with the pre-planning system by means of a web-based form. A (laptop) computer with internet access suffices to connect (securely) to the system. In the web-based form, the necessary information needs to be entered by hand. As a consequence, an airline employee needs to be present during the trial to enter the appropriate data. The employee acts as intermediate between the pre-planner and the aircraft. The employee needs to perform the following tasks for each aircraft that is inbound EHAM:

a) Communicate the active runway and transition to the aircraft.
b) Receive an ETA from the aircraft (that is based on this runway/transition).
c) Enter the ETA in the planning system.
d) Communicate the planned time back to the aircraft.
e) Enter the response of the aircraft to the planned time of arrival (accept/reject).

Option 3: Communication of ETA information through radiotelephony

> For aircraft that arrive from the east of EHAM (through MUAC airspace), it is also possible to communicate the ETA through R/T. MUAC participates in the project and will verify whether the proper transition is in the active route of the FMS. Next, they will request an ETA. Finally they will communicate a planned arrival time back to the crew.

The technical infrastructure will be set up by Mr. Dennis Nieuwenhuisen from the National Aerospace Laboratory (NLR). A standard technical infrastructure solution will be proposed for all participating airlines. Mr. Nieuwenhuisen can be contacted for technical matters considering the trial. By phone +31205113391 and by mail: nieuwenhuisen@nlr.nl

For operational questions please contact the project manager: Mr. Evert Westerveld from ATC the Netherlands (phone: +31204063558 or mail: e.westerveld@lvnl.nl) or Mr. Nico de Gelder from the NLR: phone +31205113580, email: degelder@nlr.nl