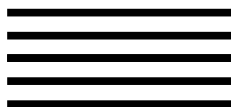


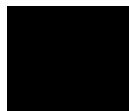
PROGRAMME FOR
HARMONISED AIR TRAFFIC
MANAGEMENT RESEARCH
IN EUROCONTROL



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EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION, EUROCONTROL



PD/3 Airborne Evaluation Pilot Briefing Guide

PHARE/AHMI/6.3.2



EUROCONTROL

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- the NLR (Nationaal Lucht- en Ruimtevaartlaboratorium);
- the RLD (Rijksluchtvaartdienst);
- the LVB (Luchtverkeersbeveiliging);
- the DLR (Deutsche Forschungsanstalt für Luft- und Raumfahrt);
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ABBREVIATIONS

| | |
|---------|--|
| AA PC | Arrival ACC Planner Controller |
| AA TC | Arrival ACC Tactical Controller |
| a/c | Aircraft |
| ACC | Area Control Centre |
| ACK | Acknowledgement |
| AHMI | Airborne HMI project |
| AM | Arrival Manager (PATs) |
| APP | Approach Centre |
| ARN | ATS Route Network |
| ARR SP | ARRival Sequence Planner |
| ARR TC | ARRival Tactical Controller (INI and ITM) |
| A-SMGCS | Advanced Surface Management Guidance and Control System |
| ATC | Air traffic Control |
| ATCO | Air Traffic Controller |
| ATD | Actual Time of Departure |
| ATIS | Automatic Terminal Information Service |
| ATFM | Air Traffic Flow Management |
| ATM | Air Traffic Management |
| ATN | Aeronautical Telecommunication Network |
| ATO | Actual Time Over |
| ATS | Air Traffic Services |
| CDU | Control and Display Unit |
| CDG | Charles-de-Gaulle Airport |
| CENA | Centre d'Etude de la Navigation Aérienne (France) |
| CFL | Cleared Flight Level |
| CFMU | Central Flow Management Unit |
| CM | Context Management, a D/L application |
| CNS | Communication, Navigation and Surveillance |
| CP | Conflict Probe (PATs) |
| CPDLC | Controller Pilot Data Link Communications, (an air-ground D/L application) |
| CT | Co-operative Tools |
| CTA | Control Area (ACC) |
| CWP | Controller Working Position |
| DAP | Downlink Aircraft Parameters, an air-ground D/L application |
| DA PC | Departure ACC Planner Controller |
| DA TC | Departure ACC Tactical Controller |
| DERA | Defense and Evaluation Research Agency |
| DEP PC | DEPARTure Planner Controller |
| DEP TC | DEPARTure Tactical Controller |
| D/L | Data Link |
| DM | Departure Manager (PATs) |
| EATCHIP | European ATC Harmonisation and Integration Programme |
| EATMS | European Air Traffic Management System |
| EEC | EUROCONTROL Experimental centre |
| EFIS | Electronic Flight Instrument System |
| EFMS | Experimental Flight Management system |
| ER PC | En-Route Planner Controller |
| ER TC | En-Route Tactical Controller |
| ETMA | Extended Terminal Manoeuvring Areas |
| ETA | Estimated Time of Arrival |
| ETD | Estimated Time of Departure |
| ETO | Estimated Time Over |
| FL | Flight Level |
| FM | Flight Manage (FDPS) |
| FMS | Flight Management System |
| FPM | Flight Path Monitor (PATs) |
| GHMI | Ground HMI project |
| HIPS | High Interactive Problem Solver |

| | |
|----------|---|
| HMI | Human Machine Interface |
| IFL | Intermediate Flight Level |
| INI | INItial approach controller (ARR TC) |
| ITM | InTerMediate approach controller (ARR TC) |
| LAD | Look Ahead Display |
| LoA | Letter of Agreement |
| LOC | LOcal Controller (Tower) |
| NAV | navigation |
| MCS | Multi aircraft Cockpit Simulator |
| MF | Metering Fix |
| MSL | Mean Sea Level |
| MSP | Multi-Sector Planner |
| NFL | Entry Flight Level |
| NLR | Nationaal Lucht- en Ruimtevaartlaboratorium(Netherlands) |
| NM | Negotiation Manager (PATs) |
| nms | nautical miles |
| OPS | Operational Specification document |
| ORG | Operational ORGanisation used as demonstration scenario |
| OSD | Operational Scenarios Document |
| OTF | Operational Task Force (PD/3) |
| PANS-RAC | Procedures for Air Navigation Services, Rules of the Air and Air traffic Services |
| PATs | PHARE Advanced Tools |
| PEL | Planned Entry Level |
| PC | Planner Controller |
| PCFL | Preferred Cruise Flight Level |
| PD/3 | PHARE Demonstration 3 |
| PDC | Pre-Departure Clearance, an air- ground D/L application |
| PF | Pilot Flying |
| PHARE | Program for Harmonised ATM Research in EUROCONTROL |
| PLCO | PLanning Co-ordination, a ground-ground D/L application |
| PNF | Pilot Not Flying |
| PS | Problem Solver (PATs) |
| PVD | Plan View Display |
| QNH | Static air pressure at mean sea level |
| RETD | Revised Estimated Time of Departure |
| RFL | Requested Flight Level |
| R/T | Radio / Telephony |
| RVSM | Reduced Vertical Separation Minima |
| SFDU | System Flightplan database Updates,(a ground-ground D/L application) |
| SID | Standard Instrument Departure route |
| SPL | System PLaN |
| STAR | STandard Arrival Route |
| STO | Scheduled Take-Off time |
| SUC | Start-Up Controller |
| TC | Tactical Controller |
| TMA | Terminal Manoeuvring Area/ Terminal Control Area |
| TOC | Top Of Climb |
| TOD | Top Of Descent |
| TP | Trajectory Predictor (PATs) |
| TWR | Tower |
| UAC | Upper Airspace Control |
| UK | United Kingdom |
| UTC | Co-ordinated Universal Time |
| WNS | Weather Nowcast Services, a D/L application |
| XFL | Exit Flight Level |
| 4D | Four Dimensional |
| 4D TN | 4D Trajectory Negotiation, (an air-ground D/L application) |

1. PD/3 Airborne Evaluation Experiment Overview

1.1 INTRODUCTION

PHARE Programme

The Programme for Harmonised Air Traffic Management Research in EUROCONTROL (PHARE) is a multi-year experimental work programme, the objective of which is "to organise, co-ordinate and conduct - on a collaborative basis – studies, experiments and trials aiming at proving and demonstrating the feasibility and merits of a future air-ground integrated ATM system in all phases of flight".

The major deliverables of the PHARE work programme are a series of real-time simulations - termed "demonstrations" – designed to fully investigate the operational concepts being studied.

The first PHARE Demonstration, PD/1, was conducted in 1995 and examined the application of computer assistance tools and aircraft equipped with 4D Flight Management Systems and datalink in the en-route scenario; while the second, PD/2, completed a similar investigation but within the TMA.

PD/3 brings together the en-route and Extended TMA experiments, extending the work to encompass a series of demonstrations defined in a plural-site environment (NLR, CENA and EEC). It concentrates on the air and ground systems that could be available in the time-scale 2005-2015 and addresses the influence of different controller working methods.

In the ground system a series of advanced system support tools are provided to assist the controller. These tools provide for departure management, en-route filtered problem detection and solving and arrival management. An ATN network and trajectory negotiation tools and system assisted co-ordination facility permit controllers to co-ordinate between sectors and Centres and to contract trajectories with the pilot.

All of these functions are made available through an integrated interface which permits the controller to share tasks with the system.

A specific evaluation on airborne aspects is conducted. An Experimental Flight Management System (EFMS) has been developed within PHARE to simulate future aircraft capabilities to predict and accurately follow 4D trajectories and communicate/negotiate these trajectories with ATC via datalink. An advanced interface allows pilots to interact graphically and to control the EFMS. Two fixed-base aircraft simulators (MCS) and a moving base A340 simulator (TUB) will be used.

At the EEC, PD/3 represents a runway to runway evaluation

involving both Controllers and Pilots of different nationalities and an evaluation team including EUROCONTROL, FAA and UK NATS staff.

1.2 MEASUREMENTS, RECORDING & REPORTING

Measurements and Recording

All recorded data, interviews, questionnaires and conversations are considered to be confidential. This data is only used by the analysis team and reference to individuals will not be made.

The measurements used in PD/3 will include :

- recordings of aircraft profile information;
- pilot interaction with AHMI;
- pilot use of R/T;
- debriefing notes;
- observation and video debriefing;
- questionnaires.

Pilots will be tasked to participate in debriefings or interviews following an exercise.

The conduct team will attempt to feed back subjective findings to pilots throughout the simulation.

The Report.

The PD/3 final report shall collate the data obtained during the measured exercises to respond to questions that have been posed concerning the PD/3 concepts.

Conclusions and recommendations shall be made on the basis of the conduct teams interpretation of your comments on the demonstrations and on the analysis of system recordings.

A copy of the final report shall be sent to you together with copies of any additional material used to publicise the results.

1.3 PD/3 SIMULATION OBJECTIVES

General Objectives (as defined by the PD/3 Operational Task Force)

1. Proving and demonstrating the feasibility and merits of a future air/ground integrated air traffic management system in all phases of flight;
2. Provide input to the definition of future European Air Traffic Management System concepts.

Specific

PD/3 shall :

1. Evaluate a future ATM concept for the time period 2005 - 2015, which supports the introduction of :
 - Multi-Sector Planning
 - Air-Ground integration

- Traffic Organisation
2. Evaluate the transitional introduction of 4D and Data Link equipped aircraft in this new ATM concept.

The operational concept explored by PD/3 attempts to keep the “human” in the loop. This is accomplished by following a “Human Centred” approach with the introduction of system support tools to assist, not replace the pilot or the controller.

1.4 OVERVIEW OF PD/3

Baseline

PD/3 will provide the controller with the opportunity to work in an EATCHIP III type environment. This is a strip-less working environment with conflict prediction tools replacing paper strips.

The controller roles in the baseline are similar to today except that there is system support to facilitate conflict detection and monitoring, and system assisted co-ordination to reduce inter sector/Centre telephone co-ordination.

There is no data link available. Traditional control methods are used.

Two baseline scenarios will be played :

1. standard route
2. direct route with RVSM (User Preferred Trajectory - UPT)

Advanced Organisation

The aim of the PD/3 Advanced Organisation is to permit a significant increase of sector traffic throughput by redistributing workload away from tactical control to both multi-sector (MSP) and sector planning control (PC).

An advanced working environment has been conceived to facilitate this aim. It includes ground-ground and ground-air data link, advanced airborne EFIS-4D FMS, and advanced ground system support tools including arrival and departure managers (AM, DM), trajectory predictor (TP) with conflict probe (CP) and flight path monitor (FPM), problem solver and trajectory editor (PS), and co-operative tools (CT) for problem detection and filtering, and a Look Ahead Display (LAD) related to the controllers planning authority.

Within this environment there will be 2 fixed based cockpit simulators (MCS) and a moving based A340 simulator from the Technical University Berlin providing us with an air - ground integrated simulation with Pilots and Controllers to fully the explore PD/3 Advanced Organisation.

Two advanced scenarios will be played :

1. standard route
2. direct route with RVSM (User Preferred Trajectory - UPT)

Gate to Gate

At the EEC the PD/3 demonstration will include sectors from departure at Charles De Gaulle (off the runway) to Amsterdam (onto the runway). This affords a gate to gate evaluation of the PD/3 concept and tools (excluding the airport environment).

MCS flights

For the purpose of the EEC Airborne Evaluation, the 2 MCS cockpits and the TUB A340 flight simulator will conduct flights along the following routes:

1. Paris-CDG to Amsterdam-Schiphol
2. Amsterdam-Schiphol to Paris-CDG
3. Zurich to Heathrow
4. Heathrow to Zurich

Operational Environment

The following sectors are used in EEC PD/3 :

| Sector Name | Role | Sector Name | Role |
|-------------|------------------|-------------|----------------|
| URUY PC | En route planner | SOUTH PC | ACC planner |
| URUY TC | En route radar | SOUTH TC | ACC radar |
| XNUN PC | En route planner | EHAM INI | Approach INI |
| XNUN TC | En route radar | EHAM ITM | Approach ITM |
| REIMS | MSP | | |
| TNTB PC | En route planner | CDG PC | ACC planner |
| TNTB TC | En route radar | CDG TC | ACC radar |
| BUUC PC | En route planner | SUDHI | ACC Feed |
| BUUC TC | En route radar | SUDLO | Feed - TWR |
| BHWS PC | En route planner | LONDO | ACC Feed |
| BHWS TC | En route radar | EAST | ACC Feed |
| MAAS | MSP | | |
| EHAM ASP | ASP | COAHI | ACC Feed |
| | | COALO | Feed TWR & App |

These sectors represent core European airspace traffic flows and provide the opportunity to evaluate complete trajectories, runway to runway, from Paris to Amsterdam.

- ◆ The separation used in en-route and ACC shall be 5 NM.
- ◆ The separation used in approach shall be 3 NM.

Vortex wake separation in approach shall have priority over 3 NM when it is greater between aircraft types.

The major airfields and runways simulated include :

| EHAM | Amsterdam (South Configuration) | |
|-------------|--|----|
| Departure | 24 | |
| Arrival | From South | 18 |
| | From East | 27 |

From West 19R

LFPG Paris Charles De Gaulle (West Configuration)
 Departure To North 27L
 To South 26R
 Arrival From North 27R

LFPO Paris Orly
 Departures 25

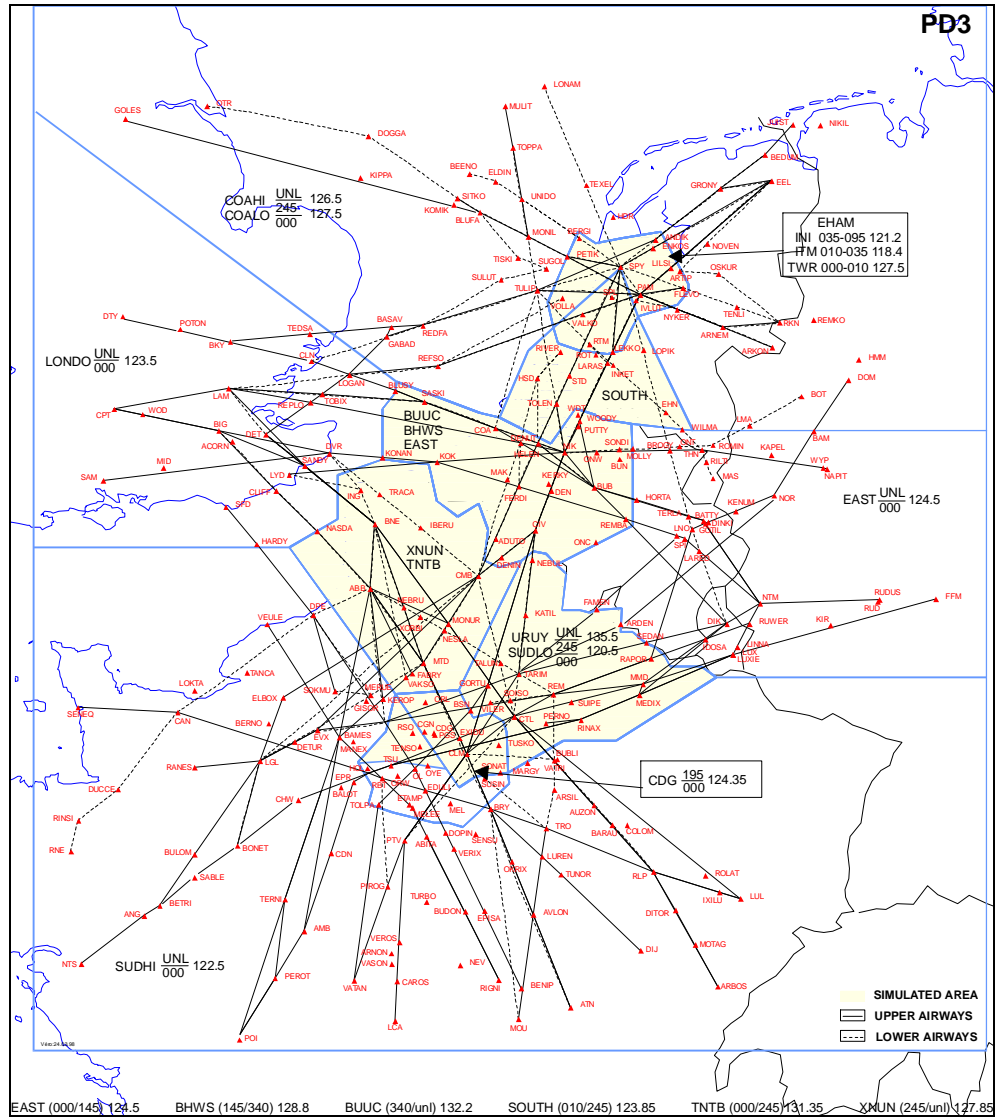


Figure 1 EEC PD/3 Airspace and Sectors

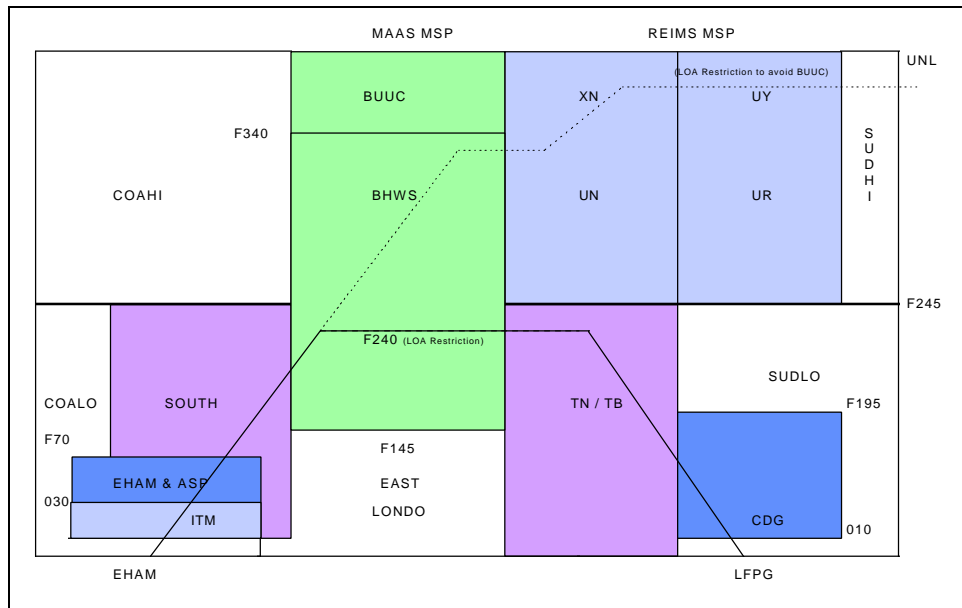


Figure 2 EEC PD/3 Sectors - Vertical View

“Free Route” and RVSM

A free route organisation shall be simulated. In fact this is represented by direct routing between navigation start and end points for over flying traffic, and from SID exit gate to STAR gate for departure and arrival traffic.

This provides a notion of User Preferred Trajectory. However, decision making remains at the controller level.

The RVSM application to be used in EEC PD/3 is the single alternate level concept which is a continuation of standard level application used at FL290 and below.

RVSM is represented by the following level allocations :

| | | | | | |
|-----|------|-----|------|-----|------|
| 290 | East | 350 | East | 410 | East |
| 300 | West | 360 | West | 420 | West |
| 310 | East | 370 | East | 430 | East |
| 320 | West | 380 | West | 440 | West |
| 330 | East | 390 | East | 450 | East |
| 340 | West | 400 | West | 460 | West |

Traffic Levels

The base level is traffic from June 1996. This will be increased by 75% and 125% for testing the different scenarios.

In the event that traffic levels prove to heavy an adjustment shall be made during the simulation.

Organisations

A total of 4 Organisations are planned in the Demonstration as already described above. These are mixtures of baseline concept without advanced tools and data link, advanced concept with tools and data link, and variations of standard routes and free routes with RVSM.

The different organisations are summarised below :

| | | | |
|----------|----------|----------|-----------------------------------|
| 0 | Baseline | 2 | Baseline with free route and RVSM |
| 1 | Advanced | 3 | Advanced with free route and RVSM |

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2. PD/3 Background

2.1 PHARE

Today's ATC system in Europe is at times unable to handle the demands made upon it. EUROCONTROL traffic growth scenarios consider that an increase of 45% might be expected in 2005 and around 150% in 2020. Flow restrictions imposed to safeguard the system from overload often lead to delays during peak periods. In many of the less busy areas in Europe, the required capacity goals can be achieved by well proven technology and procedures, representing "best current practice". In the busiest areas, however, the scope for increasing capacity through existing ATC methods and technology is limited.

Although developments regarding airspace, routes and sectorisation undoubtedly must and indeed will be pursued, changes in the technology and the process of ATC must also be envisaged if capacity and productivity gains are to be secured.

Means must be found which can improve the ATM system significantly to meet the predicted demand circa 2005-2015. This will have to be achieved whilst maintaining or improving system safety. Although improvements in the existing methods and technologies must be pursued, changes in the technology and processes of ATC must also be envisaged if system capacity and productivity gains are to be secured.

How?

The provision of automated assistance to the controllers is intended to support them in the resolution of conflicts and in planning the efficient use of the airspace. The introduction of data-link to communicate between the airborne systems and ground environment is expected to remove some of the communication load from the controller, to enable the use of onboard data thus improving the precision of the ground system's aircraft model for trajectory and conflict prediction, and in addition a limited exchange of trajectory data.

Experiments!

To evaluate the performance of new concepts taking advantage of enhanced technologies, the PHARE Programme has identified options to be investigated through a series of real time simulations entitled "**PHARE Demonstrations**". The term PHARE Demonstrations is used in the context of PHARE to describe a large scale validation activity, comprising integrated ground system, air system and air-ground datalink facilities. A Demonstration is the last step in a validation process consisting of functional testing, basic evaluation of individual tools and partial validation of subsystems of increasing complexity.



- **PD/1 and PD/2**

The first two Demonstrations PD/1 and PD/2 concentrated on the air and ground systems available in the 2000 timescale and addressed the en-route and TMA research issues separately. PD/1 and PD/2 investigated the provision of automated assistance to both Planning and Tactical Controllers and the application of datalink for air to ground communication. PD/1 and PD/2 provided a first step in the process of introducing automated tools and datalink facilities within an advanced ATC and airborne environment and of obtaining the controllers' reactions. The results of PD/1 and PD/2 provide inputs to the following PHARE Demonstration as well as help to refine the techniques used in measurement and analysis of the results.

- **PD/3**

PD/3 will provide a coherent validation, bringing together the en-route and Extended TMA results, extending the work to run a series of demonstrations defined in a plural-site environment. It will concentrate on the air and ground systems which could be available in the 2005-2015 time-scale and will address the influence of different controller working methods.

2.2 PD/3 ATC organisation

PD/3 is simulating an airspace from Amsterdam (TMA of Schiphol, SPL) up to Paris (TMA of Charles de Gaulle, CDG). The segmentation of airspace consists of:

- Upper airspace, en-route sectors, controlled by Upper Airspace Control (UAC), controlled by ER
- ETMA sectors, controlled by ACC
- TMA, with arrival and departure zones, controlled by APP

PD/3 will be take place in 3 local demonstrations at CENA (Athis-Mons), at EEC (Brétigny) and at NLR (Amsterdam).

- EEC Demonstration



The complete airspace between Amsterdam Schiphol and Paris Roissy-CDG is being simulated to investigate the concept of a Multi-Sector Planner. This additional controller position is responsible for advanced planning of the aircraft through a number of sectors - the aim of this role being to reduce the complexity of the traffic and thus reduce the workload of the individual sector controllers. Due to the influence of the surrounding sectors on the Multi-Sector Planner, and vice-versa, the EEC PD/3 Demonstration will simulate a large number of both en-route and TMA sectors

- NLR Demonstration



The work conducted in PD/1 and PD/2 examined the en-route and TMA scenarios in isolation. The NLR PD/3 Demonstration will further this work by integrating the two environments based on Amsterdam's Schiphol airport. The development of an automatic Arrival Management tool to increase the efficiency of aircraft landing at any airport will have obvious implications for the management of the aircraft in the surrounding en-route sectors. Similarly, tactical interventions made to an aircraft's trajectory prior to entry to the TMA may well have an effect on the planned arrival sequence. Such interactions between the TMA and en-route and the resulting co-ordination requirements will form the main focus of this element of PD/3.

- CENA Demonstration



The CENA PD/3 Demonstration has two main aims. First is the development and testing of an automatic Departure Manager tool to complement the Arrival Manager tool developed within PD/2 and the NLR PD/3 Demonstration. Second is the development and testing of an advanced toolset designed to assist the controller with the decision making process. This work will be centred upon Paris Roissy-CDG airport, and - as with the NLR work - will look at the interactions and co-ordination issues between the Departure Manager and the surrounding en-route airspace.

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3. CONCEPT

| | |
|---------------------------------------|--|
| Something new | PD/3 provides for the introduction of new flight management and precision navigation systems, 4D data-link communication, multi-layer planning techniques, and advanced ATC tools to improve Air Traffic Management. |
| Multi-sector environment | <p>The concept of multi-sector planning is aimed at providing potential capacity and economy improvements through traffic organisation, early planning and advance conflict resolution (deconflicting) over a larger area and up to 40 minutes before sector entry and balancing traffic flows / load between sectors.</p> <p>The objective is to reduce complexity (and not specifically to resolve separation problems) or balance sector loads to facilitate the planning controllers tasks. For REIMS MSP - complexity reduction is the primary task. For MAAS MSP - the task is primarily sector balancing (due to the layered sectorisation in this area).</p> |
| Air / Ground Integration | <p>The PD/3 concept includes 4D EFMS equipped aircraft which permit pilots to operate within the ATM system in co-operation with the controller. Pilots and controllers can define and negotiate accurate trajectories with the aim of:</p> <ul style="list-style-type: none"> • taking account of ground constraints; • permitting the controller to anticipate problem/conflict resolution in advance (up to 40 minutes). <p>This co-operative approach is expected to result in an improvement in flight economy and airspace capacity.</p> |
| Strategic and Tactical Control | <p>Control can be achieved :</p> <ul style="list-style-type: none"> • Strategically - through data-link to obtain a proposed trajectory from an aircraft and to issue modifications; • Tactically - through R/T or data link (with formalised clearances). <p>Both of these options require the ground and air systems to be updated to maintain a closed loop trajectory.</p> |
| Human centred approach | <p><u>The Air Traffic Controller and Pilot retain central roles in PD/3.</u></p> <p>A Human Centred Approach (HCA) is used in an attempt to provide an appropriate balance between system processes and human interest.</p> <p>Three layers of planning and control are introduced. This includes multi sector planning based on trajectory prediction 40 minutes ahead of real time; advanced planning for the sector planning controller, 10 minutes ahead of real time; and real time</p> |

| | |
|--|--|
| | tactical control. |
| | The roles of the sector controllers are defined in an attempt to provide each controller with complementary tasks consistent with their planning / control horizon. |
| Ground Prediction | Both ground and air have aircraft modelled trajectory predictors. This provides for air ground negotiation on clearances. |
| | When a negotiation is finished the ground system retains the down linked aircraft trajectory which reinforces the accuracy of the ground system data. |
| | This enables ATC to propose changes in advance of an aircraft's actual position with confidence that the aircraft will accurately fly a relatively optimal trajectory. |
| Experimental Flight Management Systems (EFMS) | The EFMS provides confidence in advanced planning and problem / conflict prediction through : <ul style="list-style-type: none"> • a data-link facility; • a comprehensive navigation database; • the ability to select and edit a 4D trajectory; • a graphical clearance presentation; • 4D guidance; • monitoring of the trajectory against the ATC clearance. |
| Cockpit | The cockpit will be equipped with two classes of HMI display device : <ul style="list-style-type: none"> • CDU which mirrors the current devices, used as the main interface to the current flight management systems, and which is considered as a secondary interface; • Navigation Interface which provides a 4D EFMS trajectory in horizontal and vertical display, as well as time. <p>“Drag and Drop” functionality is available for graphical manipulation of routes or constraints. A mouse type device is used for input.</p> |
| Advanced Tools | PHARE Advanced Tools (PATs) are provided to aid the controller's decision making process, facilitate the timely exchange of data and to introduce the aircraft into the planning process. |
| Advanced HMI | Controller and Pilot interactions are managed through advanced Human Machine Interfaces (HMI). These use colour, direct dialogue interaction and graphical applications to assist the controller and pilot to understand the ground / air situation. |
| R/T | R/T is limited to those cases where the TC is not able to modify or establish a contract via data-link in the available time or for 3D aircraft. A direct R/T instruction terminates a contract which will |

require re-negotiation following a period of tactical control.

Aircraft "sign on" and, frequency change "sign off" is passed via data-link and displayed on the Navigation Interface for 4D.

Data-link

Communication congestion is addressed through silent system assisted co-ordination / communication using a 4D data link and trajectory negotiation process between air and ground.

Data-link is assumed to be reliable and is mostly invisible to the aircrew and ATC. For the experiment received messages are assumed to be correct.

4D trajectory negotiation

The process of 4D control and negotiation applies a fully integrated process of air-ground and ground-ground co-ordinated dialogues via data-link, leading to trajectory "contracts".

The accuracy of prediction and navigation using 4D is expected to provide for increased capacity through trajectory contracting.

At the same time, management of traffic with different levels of equipment is achieved by integrating 4D guidance and control with short-term and tactical control (non-datalink equipped aircraft are controlled by traditional procedures, using R/T).

3D traffic is planned in the same way as 4D, however, the system translates the planning into tactical clearance advisories to be passed to the pilot in the traditional manner - R/T.

This is important as the treatment of 3D and 4D in different percentages is part of the demonstration - how do you go from today (3D) to tomorrow (4D).

The "Contract".

The "contract" is the trajectory with a manoeuvring volume around it, negotiated between air and ground, which the aircraft will fly to some point in the future, if possible, to the runway.

It is considered by ATC to be the active flight plan. When "contracted", Ground and Air operate with identical 4D trajectories.

"Sector Contract Approval"

The "sector contract approval" is a visual indication to the pilot as to how far an R/T negotiation can be extended before data link MUST be used. It is based on the current TC's area of responsibility (usually sector based).

It is given when entering a sector (on "assume control") and updated following a re-negotiation.

In the event that an SCA is about to end or has not been sent the Pilot will call on R/T to confirm the clearance limit and request SCA.

Formalised

A formalised clearance is the equivalent of a tactical clearance,

clearance.

sent by data link, which the aircraft is committed to fly.

The pilot is expected to contact the ground via R/T, if the clearance cannot be achieved.

Stability = Priority

Because 4D "contracts" provide confidence and are accurate over a long planning period, they contribute to stability. Nevertheless, re-negotiation is possible at all times.

As a result of this, 4D equipped aircraft deserve higher priority than 3D aircraft in problem solving; provided this can be achieved safely and in a common sense way.

4. PHARE Air-Ground Integration

4.1 Concept

Overview

The PHARE 4D ATM concept is based upon the assumption that the 4D trajectories of all 4D-FMS equipped aircraft under control in a certain airspace are known to ATC. 4D means that the 3D aircraft position is accurately known as a function of time. The rationale is that because ATC has accurate knowledge about all 4D aircraft trajectories, it is possible to optimise the traffic flow in the sector(s) in a way that the capacity of the airspace increases while also taking into account the pilot preferred trajectories for certain routes. Around each 4D trajectory a manoeuvring space is defined, which is called the 4D tube. At any moment of time, the 4D tube provides the allowable deviations of the 3D position. This can be represented as a moving “bubble-in-the-sky”.

Negotiation

Within the PHARE scenario 4D trajectories are negotiated using a datalink. An FMS predicted trajectory should be downlinked for approval by ATC. If this trajectory can not be approved by ATC then 4D ATC constraints will be uplinked, on the basis of which the pilot can propose a new trajectory (complying with the constraints) to ATC. If the trajectory is approved, ATC will up-link the 4D tube. The tube is a contract with ATC which has to be complied with. The aircraft is free to regenerate other trajectories as it wishes within a tube to optimise its flying path without needing to renegotiate with ATC.

4.2 Terminology

Some important terms frequently used within this document needs to be explained before we will discuss the negotiation process between aircraft and ATC in more detail:

Constraints

A *constraint* can be :

- a position to be overflown (2D constraint), similar to a normal waypoint in a route.
- an altitude at a 2D point (Altitude Constraint)
- a time to arrive at a 2D point (Time Constraint)

A constraint could be imposed by either ATC (ATC constraints) or the pilot (pilot constraints) on the optimal trajectory. An ordered set of constraints is called a *constraint list*. Based upon a constraint list a trajectory can be generated. An uplinked constraint list is called an *ATC constraint list*, a pilot entered constraint list is called a *pilot constraint list*.

Trajectory

A *trajectory* is the predicted 4D flight path of an aircraft. Given the trajectory the exact 3D predicted position as a function of time is known. Trajectories are generated based upon a

constraint list. Trajectory generation in the aircraft is always initiated by the pilot (not by the EFMS) and can be performed on the ground and during flight. A trajectory which is generated by the pilot but not yet negotiated with ATC is called a *proposed trajectory*. A trajectory which is negotiated and activated by the pilot is called the *active trajectory*.

Experimental Flight Management System

The Experimental Flight Management System (EFMS) is the FMS which will be used during the Evaluation. This FMS is specially developed to demonstrate the PHARE ATM concept. The EFMS is capable of generating 4D trajectories meeting constraints and negotiating those trajectories with ATC using a datalink. It should be emphasised that the EFMS is *not* a complete FMS offering all functionality which you normally expect to find on a FMS, such as extensive weight and balance calculation, take-off performance calculation, etc... The EFMS does provide basic FMS functionality plus advanced datalink functionality.

4.3 Trajectory Negotiation

Within the PHARE ATM concept there are three variants of the trajectory negotiation process defined:

- Standard Trajectory Negotiation
- Formalised Clearance Uplink
- Pre-emptive Trajectory Downlink

In the following sections all three variants are discussed in more detail

Standard Trajectory Negotiation

Before take-off every flight will start with a pilot initiated standard trajectory negotiation sequence. After the first negotiation has taken place, the trajectory may be renegotiated by either ATC or the aircraft.

Pilot initiated

First we will discuss the *pilot initiated standard negotiation* starting with the generation of a pilot preferred 4D trajectory in the aircraft. Before take-off the preferred trajectory normally will be based upon constraints complying with company route needs and SID/STAR procedures. The end of the trajectory will be in most cases the interception point of the ILS beam of the landing runway.

During a flight, renegotiation of the 4D trajectory may be initiated by the pilot due to for example bad weather areas or heavy turbulence conditions. Once the pilot preferred 4D trajectory is available it should be downlinked to ATC for approval.

ATC may respond by uplinking ATC constraints or by uplinking a tube. In the case ATC constraints are uplinked, ATC could not accept the downlinked pilot preferred trajectory because of a conflict with other traffic. A new trajectory needs to be generated by the pilot which takes into account the uplinked ATC

constraints as well. After checking the resulting modified trajectory, the pilot should downlink the trajectory in order to obtain a tube.

By uplinking a tube, ATC indicates that they accept the downlinked trajectory and that an ATC contract is made. Immediately after uplinking a tube the first part of it will be cleared by ATC to fly. Under normal circumstances during flight progress the clearance will be one or more times extended along the tube.

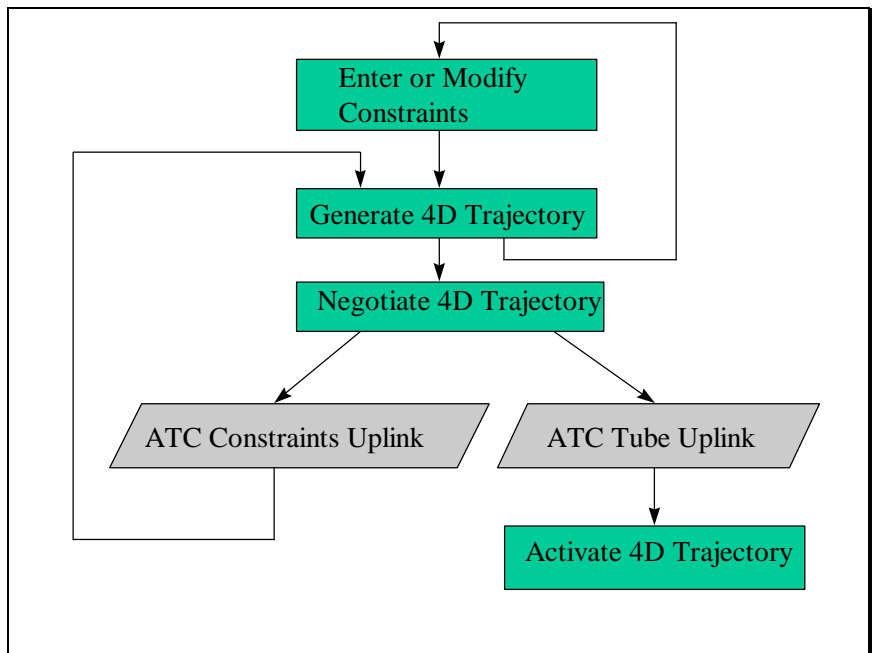
The pilot is expected to contact ATC via R/T if the next clearance is not received timely.

ATC initiated

ATC initiated standard negotiation will start with the uplink of ATC constraints indicating that the current active ATC contract needs to be modified. Analogues to the pilot initiated case, as described above, the pilot needs to answer the uplink by generating a new trajectory complying with ATC constraints.

By downlinking the resulting trajectory the pilot may expect that a new tube will be obtained, from which the first part will be cleared to fly.

Figure 3: Standard Negotiation Process



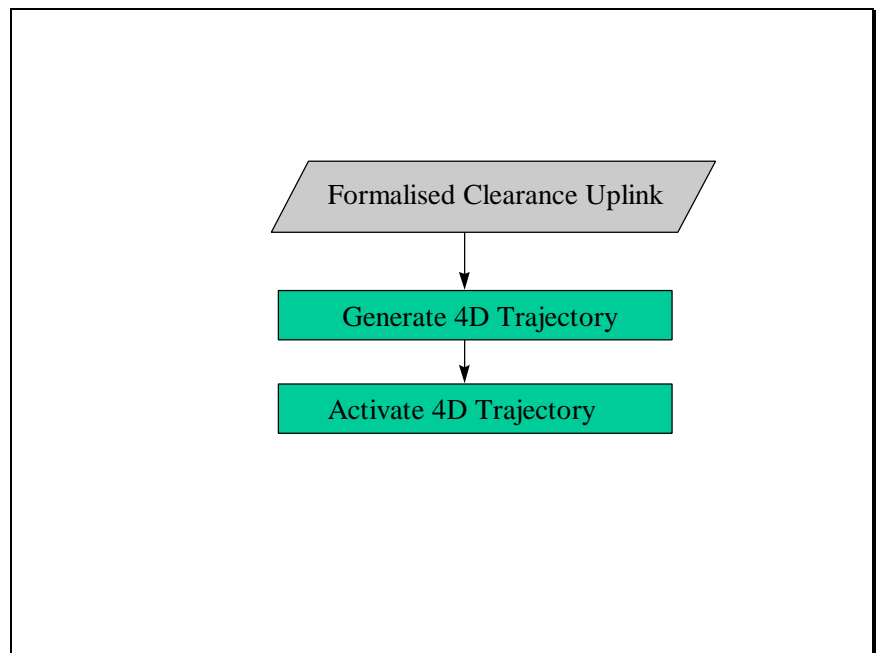
Formalised Clearance

A formalised clearance uplink is a tactical ATC directive overruling the current active ATC contract. A formalised clearance is an uplink of a constraint list, through which a 4D trajectory should be generated succeeded by an immediate activation of the resulting trajectory.

The trajectory does not need to be negotiated like would have been necessary in the case of an ATC initiated standard negotiation, because the trajectory is already cleared to fly. In

Figure 4 the steps needed to handle a formalised clearance by the pilot are shown:

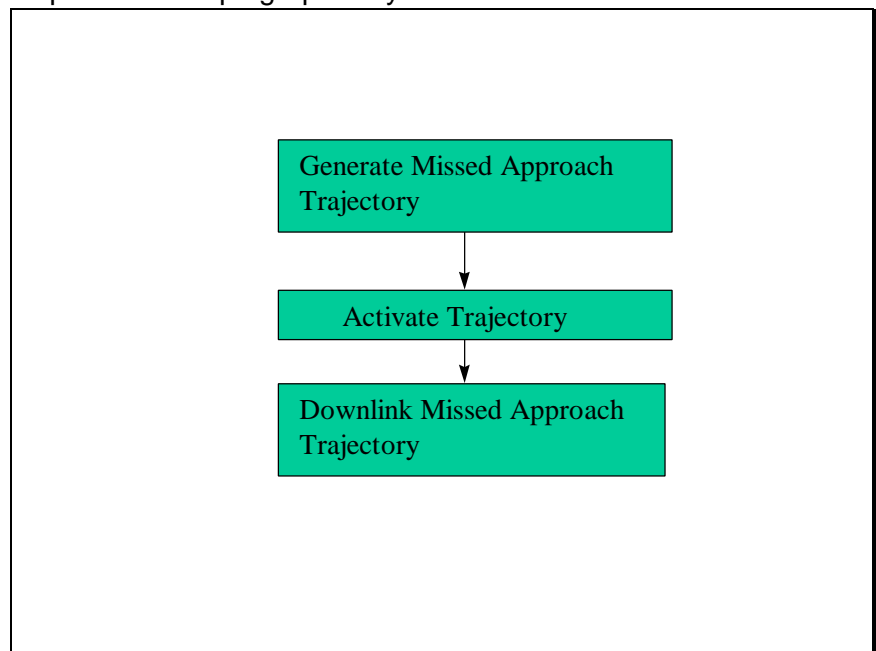
**Figure 4:
Formalised
Clearance Uplink**



**Pre-emptive
Trajectory
Downlink**

Only in the case of the initiation of a Missed Approach procedure will a pre-emptive trajectory be downlinked by the crew. A pre-emptive trajectory is downlinked after generation and activation of the missed approach trajectory. Figure 5 illustrates the sequence of steps graphically:

**Figure 5: Pre-emptive Trajectory
Downlink**



5. Airborne Human Machine Interface

5.1 Introduction

The airborne evaluation experiment will focus on the planning and negotiation task of the pilot not-flying and the monitoring task of the pilot-flying. These tasks will be carried out using an interactive navigation display (NAV display) and a Control and Display unit (CDU).

On the photo below an example flight deck configuration is shown. The CDU is located on the left side of the pilot, PFD and NAV display are located in front of the pilot, and the trackball is located on the right side of the pilot.

The trackball is controlling the position of a cursor on the NAV display. By moving the cursor softbuttons on the NAV display can be selected or waypoints can be inserted and/or removed by direct manipulation. On the trackball a button is mounted which is used to select graphical objects on the NAV display.

Figure 6: EEC MCS with AHMI integrated

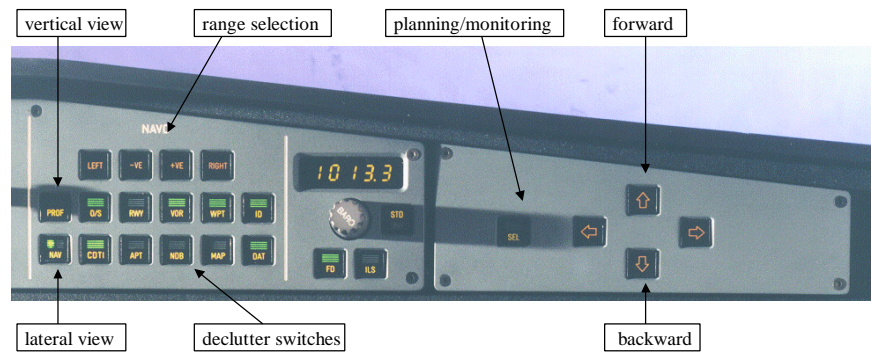


5.2 NAV Display

NAV Modes

The NAV display will be used mainly for planning and negotiating a trajectory and for monitoring the flight progress. Therefore, the NAV display has two main modes of operation: *planning mode* and *monitoring mode*. Both modes support a *lateral* and *vertical* trajectory view. All four modes can be selected on the Display Control Panel shown in the next figure:

**Figure 7: MCS
Display Control
Panel**



**Graphical
Manipulation**

Besides the standard Display Control functionality (such as range selection, mode selection and declutter switches) additional interactive planning and negotiation functionality is provided on the NAV display itself. In the planning mode the pilot constraint list can be modified by direct graphical manipulation using the trackball. The following type of constraint list modifications can be carried out in planning mode:

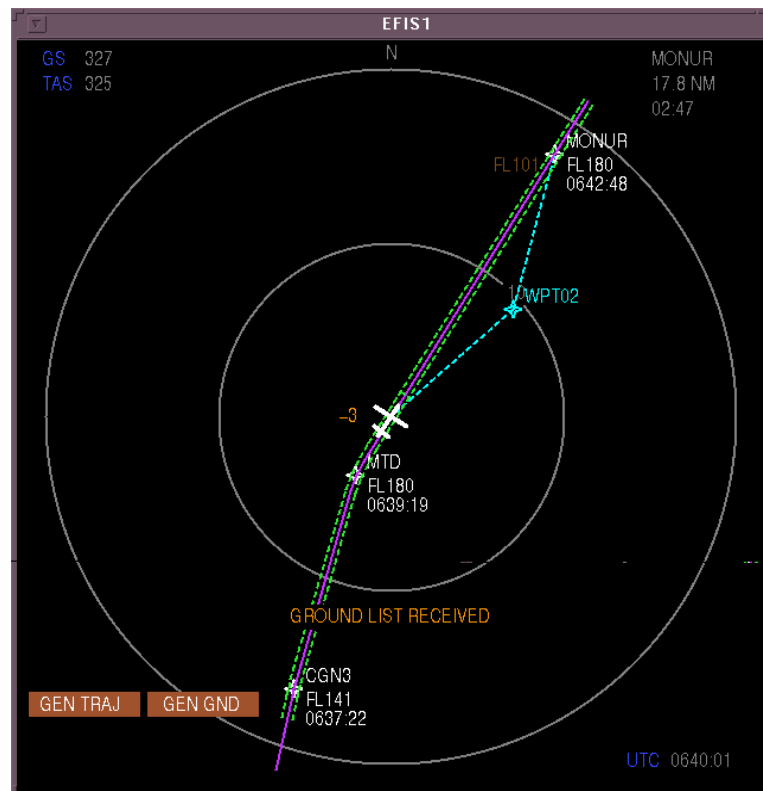
- insert or remove a waypoint in the pilot constraint list (lateral view)
- add, modify or remove an altitude constraint (vertical view)
- modify a Cruise Flight Level (vertical view)
- perform a direct to operation (lateral view)

All these type of modifications can be performed by dragging and dropping graphical objects on the display using the trackball. An example of the lateral planning mode is shown in Figure 8.

Lateral Planning

The lateral planning mode also enables the pilot to walk through the pilot constraint list by pressing the arrow up/down buttons on the Display Control Panel.

Figure 8: Lateral Planning NAV Display



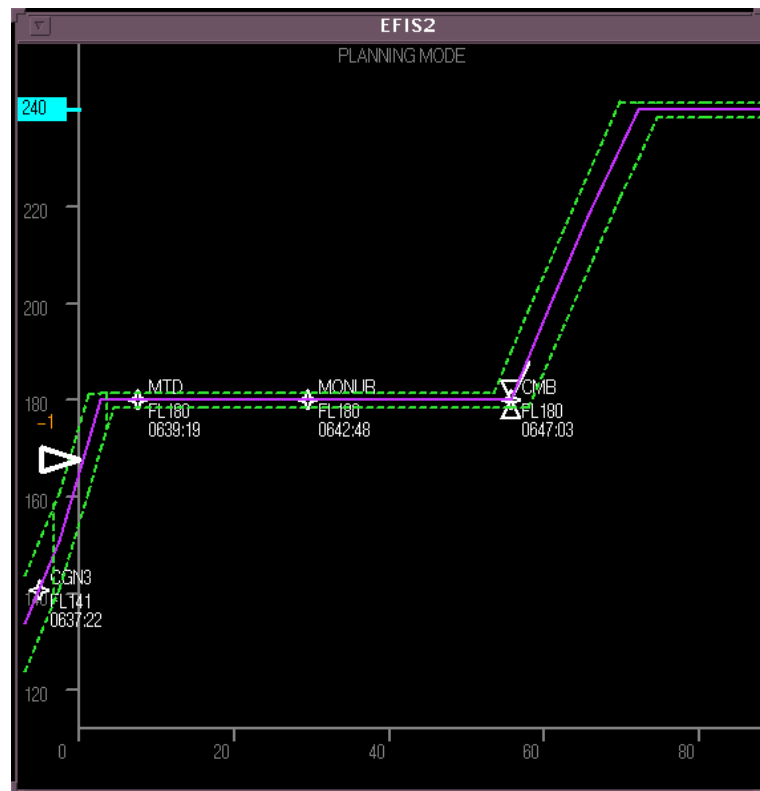
Vertical Planning

In order to add, modify or remove an altitude constraint, the vertical planning mode should be selected of the NAV display. An example of this display is shown in Figure 9.

The vertical planning mode presents the flight profile in an altitude/along-track frame. The along-track range is pilot selectable. The altitude range is automatically selected by the system. The altitude constraints are presented as triangle symbols and can be selected in order to modify the constraint window or remove the entire altitude constraint.

The vertical planning mode also allows for changing the cruise flight level by moving the cruise flight level indicator on the altitude axis using the trackball. In Figure 9 the cruise flight level is 240.

Figure 9: Vertical Planning NAV Display



Soft Buttons

Based upon the pilot constraint list a trajectory can be generated, negotiated and activated by selection buttons on the NAV display. The following functions are provided:

- generate trajectory based upon pilot constraint list
- generate trajectory based upon ATC constraint list
- negotiate trajectory (Standard Negotiation)
- activate trajectory
- downlink active trajectory (Pre-emptive Trajectory Downlink for Missed Approach only)

Note that the above listed functions are available only if the context allows for it. For example, the 'downlink active trajectory' function will only be available if there is an active trajectory defined.

Lateral Monitoring

The monitoring mode enables the pilot to monitor aircraft progress relative to the active 4D trajectory and ATC clearance. Similar to the planning mode two viewing modes are available: lateral and vertical. An example of the NAV display in lateral monitor mode is shown in Figure 10:

Figure 10: Lateral Monitoring NAV Display

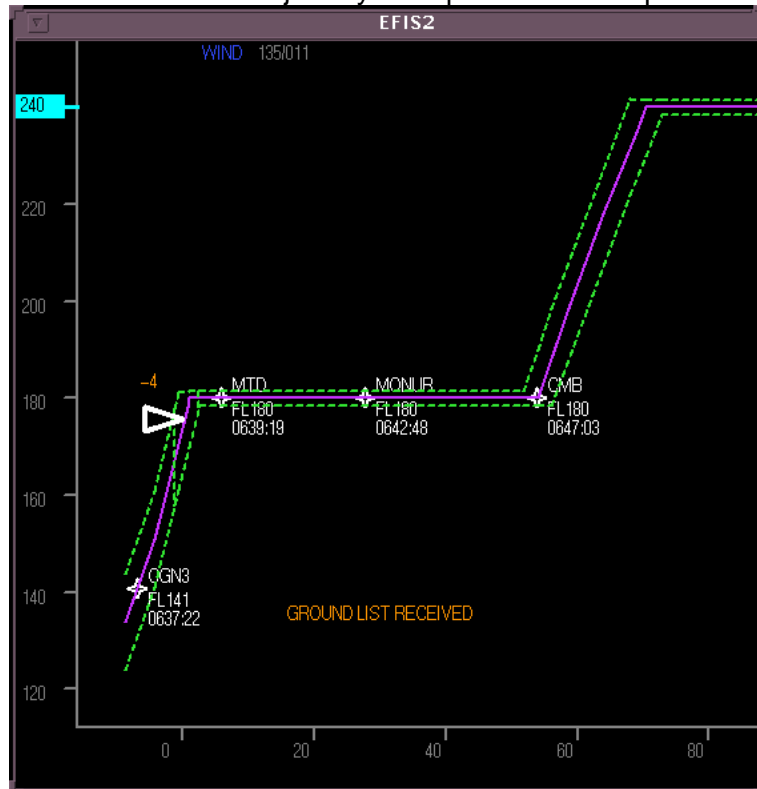


Vertical Monitoring

An example of the NAV display in vertical monitoring mode is shown in Figure 11.

Above the aircraft symbol the time error is displayed. At each waypoint the identifier, altitude and estimated time over are presented. Around the aircraft symbol the bubble is shown. Around the whole trajectory the uplinked tube is presented.

Figure 11: Vertical Monitoring NAV Display



5.3 Cockpit Display Unit

Usage The CDU will be used mainly for initialisation of the EFMS, company route selection, detailed trajectory planning and monitoring flight progress. However, all functionality which is provided on the NAV display is also available on the CDU.

Figure 12: AHMI CDU



Buttons The following main entry buttons are available on the CDU:

- **INIT** gives access to the initialisation page of the EFMS. This entry allows selection of the company route, initial fuel, weight information and estimated take-off time. Also origin airport and destination airport related information can be obtained using the INIT entry.
- **RTE** gives access to the top level view of the pilot constraint list, proposed trajectory or active trajectory. This entry allows for SID/STAR and E-R segment oriented modifications and enables the generation and activation of a trajectory.
- **LEGS** gives access to the legs of the pilot constraint list, proposed trajectory or active trajectory. This entry allows for lateral revisions or vertical revisions of the pilot constraint list, such as adding or removing constraints or defining a holding. By pressing the '←' and '→' arrow keys meteo and tube information related to the trajectory can be obtained. Similar to the RTE page, the LEGS page also enables the generation and activation of a trajectory.
- **ATC** gives access to datalink related functions, such as trajectory negotiation and review of an uplinked ATC constraint list.
- **PROG** gives access to flight progress information. The lateral, vertical and time error with respect to the current ATC contract are shown.
- **DIR TO** enables a 'direct to' to a specific waypoint or navaid.
- **REF** gives access to the meteo database and a meteo reset function.
- **PERF** enables to monitor and/or modify EFMS performance parameters.

Annunciators The CDU has four state annunciators. Two are located on the left side, two on the right side. These annunciators give information about the state of:

- guidance system
- datalink connection
- scratch pad message queue length
- EFMS system

Links with NAV

The NAV display and CDU display are automatically linked if the NAV display is in lateral planning mode and if at the same moment the CDU shows the lateral revision page. In this situation the lateral revision page 'follows' a walk through the pilot constraint list on the NAV display by pressing the 'forward' and 'backward' buttons. Also, if the '↑' and '↓' arrow keys are pressed on the CDU in order to walk through the pilot constraint points, the NAV display will follow by showing the appropriate waypoint in the centre of the display.

The same situation occurs if the NAV display is in vertical planning mode and if at the same moment the CDU shows the vertical revision page. Also in this case the NAV display and CDU display are automatically linked.

Quick Reference

In Annex A , a quick reference card can be found which includes the main operations needed for participation in the evaluation experiment.

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6. PHARE Airborne Evaluation

6.1 Introduction

A measured evaluation will take place at the Eurocontrol Experimental Centre (Bretigny) using two fixed-based cockpit simulators.

In addition, flight demonstrations of the AHMI will take place using the DERA BAC1-11 in conjunction with the CENA ground system, and also using the NLR Citation aircraft and NLR ground system.

6.2 Objectives

Evaluation Objectives

The main objective of the PD/3 Airborne evaluation is to determine whether the facilities provided in the cockpit enable the crew to adequately and safely operate the aircraft within the PHARE integrated air/ground strategic ATM environment

Specific

The operational effectiveness of the AHMI/EFMS will be determined with respect to the following questions:-

- To what extent is the goal of an action accomplished using the AHMI/EFMS?
- How much effort is needed by the pilot to accomplish the goal using the AHMI/EFMS?
- How satisfied is the pilot with the method used to accomplish the goal using the AHMI/EFMS?

Operational Situations

The following operational situations will be covered during the Airborne evaluation (in the cockpit simulators and also during the demonstration flights):-

- FMS Initialisation
This will include route selection, performance parameter selection/checking, etc.
- Strategic Trajectory Negotiation
The evaluation will determine the effectiveness of the AHMI/EFMS for carrying out the strategic trajectory negotiation process as implemented within PD/3. The following activities will be addressed:
 1. pilot route modification and evaluation
 2. pilot initiated trajectory negotiation (including prior to take-off)
 3. ATC initiated trajectory negotiation
 4. ATC constraints evaluation

5. ATC Contract evaluation and execution (including Sector Contract Approval)
6. Formalised Clearance handling
7. Missed Approach (Pre-emptive trajectory)

- **Monitoring 4D Strategic Operation**
The effectiveness of the AHMI/EFMS in allowing the crew to satisfactorily monitor aircraft operation and progress along the route, relative to the strategic 4D clearance, will be determined.
- **Tactical Flight Operations**
AHMI/EFMS effectiveness for managing the transitions between tactical ATC control and strategic ATC control will also be evaluated in the following circumstances:
 1. from 4D strategic contract operation to tactical ATC control
 2. from tactical ATC control to re-establish 4D strategic operation based upon a new negotiated contract

Navigation Display/CDU Integration

The operating method and information presentations on the Navigation Display and the CDU have been made consistent as far as possible within the constraints of the ND mainly giving a graphical representation, and the CDU giving only alphanumeric data. The two display devices are integrated during route modifications, with the appropriate information being automatically presented on both.

The Airborne evaluation based on questionnaires, debriefings and recordings will determine the degree of pilot satisfaction with this level of integration and consistency

Crew Resource Management

In addition to evaluating the cockpit facilities when operating in the PHARE ATM environment, the Airborne evaluation will also address the basic principles of the crew resource management aspects of the PHARE ATM concept in normal aircraft operations. The Pilot Flying (PF) will be tasked with monitoring the aircraft operation and performance relative to the negotiated clearance, and implementing all tactical ATC instructions. The Pilot Not Flying (PNF) will be tasked with setting up the FMS, selecting and modifying routes, carrying out all negotiations with the ground system, implementing frequency changes, and replying over R/T to any ATC tactical instructions.

The Airborne evaluation will determine whether both crew members are able to successfully maintain full situational awareness, while at the same time being able to monitor vital actions and achieve safe aircraft operation

6.3 Sites

EEC experiment

The evaluation experiment will be carried out at EEC using two fixed-base cockpit simulators. In Figure 13 one of the simulators is shown.

The left and right NAV display operate independently of each other. The Display Control Panel is mounted above the NAV display on both sides (see also figure 5). In between the left and right pilot seats two CDU's can be found which also operate independently of each other. The CDU has hardware buttons to select the appropriate CDU page and hardware line select keys to select the desired data field. The aircraft model used will be representative in terms of thrust and aerodynamic performance of either a B747-200 or of an A310-200.

**Figure 13: EEC
Cockpit Simulator**



DERA demonstration flights

DERA will carry out demonstration flights in BAC 1-11 aircraft using the ground system of CENA at Athis-Mons.

The left cockpit seat demonstrates the use of an interactive NAV display and CDU for trajectory planning and negotiation tasking. The display control panel for the NAV display is implemented in hardware. The CDU in between the two seats is landscape oriented and has a touchscreen: line select keys and page/data entry buttons are selected by touching the display. The right cockpit seat in the BAC 1-11 is for the safety-pilot.

**Figure 14: DERA
BAC 1-11
Demonstration
Cockpit**



**NLR
demonstration
flights**

The NLR will carry out demonstration flights using the Citation II aircraft. In Figure 15 the pilot flying seat is shown on the right cockpit seat. In Figure 16 the pilot not-flying seat is shown just behind the right cockpit seat.

The pilot flying will fly the aircraft manually using a PFD enhanced with additional 4D information. The pilot non-flying will use a touchscreen CDU and interactive NAV display to plan and negotiate trajectories. The display control panel of the NAV display is implemented as an additional window on the screen. Both NAV display and the display control panel (read: window) are operated by the trackball. The CDU is portrait oriented.

**Figure 15: NLR
Citation Pilot Flying
Position**



**Figure 16: NLR
Citation Pilot Not
Flying Position**



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ANNEX A - Quick Reference Guide AHMI

| Operation | CDU | NAV |
|---|--|--|
| Initialisation FMS | | |
| define co route | INIT select co route | - |
| modify cfl | INIT select cfl | VERT PLAN select cfl |
| define zfw | INIT select zfw | - |
| define fob | INIT select fob | - |
| Planning | | |
| insert wpt | LEGS LAT REV insert next wpt | LAT PLAN select leg select insertion pos |
| remove wpt | LEGS LAT REV delete wpt | LAT PLAN triple select wpt |
| direct to | DIR TO select wpt/enter wpt wpt | LAT PLAN or LAT MON select aircraft select direct to wpt |
| insert altitude cstr | LEGS VERT REV insert alt cstr | VERT PLAN select wpt on x-axis drag to cstr alt |
| remove alt cstr | LEGS VERT REV CLR select alt cstr | VERT PLAN triple select alt |
| insert time cstr | LEGS VERT REV insert time cstr | - |
| remove time cstr | LEGS VERT REV CLR select time cstr | - |
| Negotiation | | |
| standard negotiation (trajectory downlink) | RTE or LEGS (re-)plan trj generate ATC negotiate | PLAN (re-)plan trj generate negotiate |
| standard negotiation (tube uplink) | RTE or LEGS act | act |
| standard negotiation (ATC cstr uplink) | ATC < ground rte gen ground ATC negotiate | generate negotiate |
| formalised clearance | ATC <ground rte generate activate | generate activate |
| pre-emptive trj dwn link | RTE or LEGS generate act rte ATC downlink active | |

ANNEX B - Typical flight scenario

| Event | | Aircraft | Datalink | ATC |
|---|----|---|-----------------------|---------------------------------|
| Pre-Flight Negotiation | | | | |
| Pre Take-Off 20mins ahead | 1 | Pilot enters company route, cfl etc... | | |
| | 2 | Predict trajectory | | |
| | 3 | Negotiate trajectory | ↓Trajectory | |
| | 4 | | ↑ATC Constraints | Uplink ATC constraints |
| | 5 | Evaluate ATC constraints and predict new trajectory | | |
| | 6 | Negotiate trajectory | ↓Trajectory | |
| | | | ↑Tube | Uplink ATC Tube |
| Push Back/Taxi | 7 | | ↑ATC Constraints | Uplink modified constraint list |
| | 8 | Predict trajectory | | |
| | 9 | Negotiate trajectory | ↓Trajectory | |
| | 10 | | ↑Tube | Uplink Tube |
| | 11 | | | R/T clearance to "Line up" |
| Line Up | 12 | | | R/T clearance to "Take Off" |
| | 13 | Activate trajectory | ↓Activated | |
| | 14 | | ↑Clearance | Uplink Clearance |
| Take Off | 15 | | | |
| After Take Off | 16 | Start guidance | | |
| ATC Initiated Standard Negotiation | | | | |
| | 1 | | ↑ATC Constraints | Uplink ATC constraints |
| | 2 | Evaluate ATC constraints and predict new trajectory | | |
| | 3 | Negotiate trajectory | ↓Trajectory | |
| | 4 | | ↑Tube | Uplink ATC Tube |
| | 5 | Activate trajectory | ↓Activated | |
| | 6 | | ↑clearance | Uplink clearance |
| Pilot Initiated Standard Negotiation | | | | |
| | 1 | Modify pilot constraints | | |
| | 2 | Predict new trajectory | | |
| | 3 | Negotiate trajectory | ↓Trajectory | |
| | 4 | | ↑Tube | Uplink ATC Tube |
| | 5 | Activate trajectory | ↓Activated | |
| | 6 | | ↑clearance | Uplink clearance |
| Formalised Clearance | | | | |
| | 1 | | ↑clearance | Uplink clearance |
| | 2 | Predict new trajectory through formalised clearance | | |
| | | | | |
| | 3 | Activate trajectory | ↓Activated Trajectory | |