PROGRAMME FOR HARMONISED AIR TRAFFIC MANAGEMENT RESEARCH IN EUROCONTROL

PHARE

EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION EUROCONTROL

DOC 99-70-01

Volume 1 of 4

Final Report of PHARE Demonstration 3 (PD/3)

PHARE/EEC/PD3-7.1/FR; 1.0

EUROCONTROL

EUROCONTROL

96 rue de la Fusée

B-1130 BRUXELLES

Prepared by: **Marc Bisiaux, EEC**

Date: **June 2000**

REVISION HISTORY

Date	Revision Number	Reason for revision
17/9/98	0.1	Initial outline
28/9/99	0.7	Successive inclusion of materials and results outlines
04/11/99	0.8	Inclusion of remarks from DRG
05/04/00	0.9	Inclusion of elements from final PD/3 reports and remarks from M.v.Gool
19/06/00	1.0	Inclusion of comments from H. Schroeter

DOCUMENT APPROVAL

NAME		SIGNATURE	DATE
Marc Bisiaux	**PD/3 Project Leader**		19-06-2000
Jean-Louis Martin	**CENA PD/3 Project Leader**		19-06-2000
Wim Post	**NLR PD/3 Project Leader**		19-06-2000
Robert Graham	**EEC PD/3 Project Leader**		19-06-2000
Mick Van Gool	**PHARE Demonstrations Coordinator**		19-06-2000
Helmut Schröter	**PHARE Programme Manager**		19-06-2000

EXECUTIVE SUMMARY

The term ***PHARE Demonstration*** 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. The first two Demonstrations PD/1 and PD/2 concentrated on the air and ground systems available in the 2000 time-scale and addressed en-route and TMA research issues separately.

PD/3 constituted a further step towards the validation of a long-term air-ground integration concept, but more specifically concentrated on the validation of the medium-term system where the controller remains a key control element. It was the intention to prove and demonstrate the feasibility and merits of future air/ground integrated air traffic management systems in all phases of flight.

Another objective was to provide input to the definition of future European Air Traffic Management System concepts.

Three functional elements were at the core of the PD/3 concept :Multi-Sector Planning, Air-Ground integration, and Traffic Organisation. The concept definition comprised the transitional introduction of 4D and Data Link equipped aircraft in this new ATM concept. The demonstration further progressed the introduction of advanced assistance tools, planning functions, including the Arrival and Departure Manager Tools, and the extension of the concept of 4D trajectory negotiation and planning.

PD/3 was run as a collaborative project. At the start of the project in 1993 it was defined as a multi-site demonstration involving several interconnected sites, however, due to timescale and resource limitations the PD/3 demonstration was finally run as a "plural-site" demonstration.

The PD/3 experiment conducted at the EEC would have demonstrated the full gate-to-gate concept, but suffered from severe limitations of the simulation platform which reduced the scope of the trial effectively to a large scale system test. *However, feedback from the conduct of the PD/3 simulation, the training phase and from the controllers' experiences of the tools and concept has been collated and analysed.*

The CENA PD/3 trials, concentrating on the departure to en-route flight phases, have achieved their objectives in terms of providing a sufficient number of validated runs, which have being analysed. Highlights of these results are given in this report.

The trials at NLR, concentrating on the en-route into arrival flight phases, did not fulfil the objective to achieve measured results. However, a qualitative assessment of the advanced PHARE concept could be made.

The airborne trials either through the use of real aircraft or cockpit simulators have further shown the feasibility of the trajectory negotiation and provided feedback on the pilot's role and Airborne Human Machine Interface in this context.

Acknowledgements

The final PHARE Demonstration has been made possible by the contribution of all the PHARE participants, their teams as well as the simulation teams of the participating sites, including Experimental Aircraft crews and support. They all must be thanked for their invaluable contributions.

Pilots and Air Traffic Controllers who took part in the preliminary experiments and the demonstrations have been essential to the project, through their participation and contributions.

Particular thanks are expressed to the project leaders involved in PD/3 and their teams:

PHARE Cell : Mick Van Gool (EHQ)

PD/3 : Pascal Huet (CENA), Jean-Louis Martin (CENA), Robert Graham (EEC), Wim Post (NLR).

PD/3 Task Forces Leaders and Participants and in particular :

Jean-Pierre Nicolaon (EEC), Hugo de Jonge (NLR), Beatrice Cazard (CENA), Roderick McGregor (EEC), Robert Maddock (EFMS Integration Team)

Peter Martin (EEC), Christiane Dujardin (CENA)

Airborne Programme: Ed Bailey (EHQ), Uwe Teegen (DLR), Ronald Verhoeven (NLR), Reg Harlow (DERA), Eric Hoffman (EEC)

GHMI: Peter Jorna (NLR), Isabelle Pichancourt (EEC), Marian Van Blanken (NLR), Didier Pavet (CENA),

PATs: Ian Wilson (EHQ)

CMS: Jean-Raymond Velten (CENA)

Meteo: Dave Underwood (NATS)

PATN: Boudewijn Overgaauw (CENA), Gérard Mittaux-Biron (CENA)

Validation: Rob Whitaker (NATS)

Marc Le Guillou, CENA, who died on 8 September 1996, will remain in our memories; he had a major role in the PHARE programme and inspired largely the PD/3 project.

LIST OF CONTENTS

LIST OF FIGURES

Page intentionally left blank

1 INTRODUCTION

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.

To evaluate the performance of new concepts taking advantage of enhanced technologies, the PHARE Programme 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.

The first two Demonstrations PD/1 and PD/2 concentrated on the air and ground systems available in the 2000 time-scale and address en-route and TMA research issues separately.

PD/3 was a joint programme of the PHARE partners, hosted by EEC, NLR and CENA, and with significant contribution from NATS and DLR.

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

1.1 PD/3 OBJECTIVES

PD/3 constituted a further step towards the validation of a long-term air-ground integration concept, but more specifically concentrated on the validation of the medium-term system where the controller remains a key control element. PD/3 was designed to be a multi-sector, multi-centre demonstration involving a number of research centres' ground and airborne facilities with the expected functionality associated with application time-scale 2005-2015.

The PD/3 *General Objectives were defined as:*

- Proving and demonstrating the feasibility and merits of future air/ground integrated air traffic management systems in all phases of flight.
- Providing input to the definition of future European Air Traffic Management System concepts

The validation of the feasibility of the advanced PD/3 ATM operational concept in accordance with the way the foreseen enhanced CNS technologies or automation capabilities can be used and integrated to support it was planned to include the following elements:

- Three functional elements:
    - Multi-Sector Planning,
    - Air-Ground integration,
    - Traffic Organisation,
- The transitional introduction of 4D and Data Link equipped aircraft in this new ATM concept

The PD/3 concept keeps the man in the loop by following a « Human Centred Approach » with the introduction of new tools to support the controllers in the environment characterised by the above mentioned functional elements.

The provision of automated assistance to the controllers was 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 was expected to remove some of the communication load from the controller, to enable the use of onboard data to improve the precision of the ground system's aircraft model for trajectory and conflict prediction, and in addition a limited exchange of trajectory data.

En-Route Aspects

- introduction of advanced assistance tools among which co-operative tools aiming at organising the traffic in a « human-in-the-loop » philosophy;
- introduction of multi-sector planning optimising the way the traffic is organised at a scale larger than the traditional sector;
- introduction of 4D trajectory negotiation and 4D planning in a multi-sector environment (some issues concerning for example the mode of co-operation between air and ground, the role of the aircraft and the pilot in the future ATM concept, or the controller or pilot HMI are covered by this).

TMA (ETMA[1]) Aspects

- introduction of advanced assistance tools,
- introduction of planning functions, including the Arrival and Departure Manager Tools,
- introduction and extension of the concept of 4D trajectory negotiation and planning.

Collaboration objectives

PD/3 included collaborative objectives :

- To demonstrate the capability for a group of ATC research establishments in Europe to join their skills and efforts to specify, design and implement common demonstration environments based upon a harmonised architecture and integrating the components developed under other PHARE projects;
- To demonstrate the feasibility to elaborate and run large co-ordinated demonstrations taking advantage of the facilities available in the various establishments.

[1] The Extended TMA (ETMA) environment covers the APP sectors and also the ACC terminal sectors dealing with the descending and climbing traffic to and from a concerned airport. On the other hand "En-route" concerns only the ACC sectors outside the extended TMA and dealing mainly with cruising traffic.

1.2 PROJECT CONTEXT

Although initially defined as a multi-site demonstration involving several interconnected sites, the PD/3 demonstration was finally run as a “plural-site” demonstration. This implied v*alidating different and complementary aspects of the evaluated concepts in a co-ordinated way on three main sites.*

- CENA at Athis-Mons - Focus on Departure aspects
- NLR at Amsterdam - Focus on Arrival Aspects
- EEC at Brétigny - Gate to Gate evaluation

One important aspect of PD/3 concerned the integration of the en-route and ETMA concepts with the demonstration of a planning function supporting the transition between the en-route and TMA flight phases.

PD/3 was defined as a set of real-time simulations running two organisations

- The baseline organisation is a reference close to the today’s operational situation
- An Advanced Organisation including the advanced assistance tools in an air/ground integrated environment.

Simulation environment

The airspace simulated comprise parts of Amsterdam TMA, Maastricht upper airspace, Reims ACC, Paris ACC and Roissy Charles de Gaulle TMA, together with TMA and En-route adjacent sectors and multi-sector planning areas.

Airspace data for the reference organisation was taken from the CFMU database as of 21 June 1996.

The advanced organisation used the reference organisation data as start point but evolve in accordance with the PD/3 operational concept to cater for future airspace structures.

A baseline for comparison

The PD/3 concept was designed to be validated against a baseline organisation. The implementation of this baseline differed depending on the focus at each site.

The roles and the procedures used for the Baseline Organisation were based on current practices such as those used in the Dutch and the French ATC but with some assistance functions conveyed by the electronic environment such as :

- electronic co-ordination,
- entry and exit aids,
- vertical aid window,
- trajectory prediction (flight leg),
- conflict probing (in en-route areas)
- arrival sequencing and scheduling (within TMA only).

The computer assistance was strip-less and the air-ground communications were performed via R/T (no air-ground data-link available).

The Planning Controller played an assistant role to the Tactical Controller, proposing co-ordinations for both entry and exit conditions. The Tactical Controller was responsible for separation, and performed most of the tasks, mainly monitoring, conflict detection and resolution.

1.3 REPORT STRUCTURE

PD/3, as a plural-site experiment, has produced a a set of four main reports with their respective annexes under the reference DOC 99-70-01 containing :

- Final report of PHARE Demonstration 3 (PD/3) Volume 1 of 4,
- CENA PD/3 Final report Volume 2 of 4, (in 2 parts)
- EEC PD/3 Final report Volume 3 of 4,
- NLR PD/3 Final report Volume 4 of 4.

This final PD/3 report gives a synthetic overview of the elaboration of the PD/3 Demonstrations, mainly from a general viewpoint, starting from the launching of this series of final experiments to their actual implementation and run.

While this Introduction has given a quick overview of the PD/3 project objectives and associated concepts, the rest of the report is structured as follows:

Chapter 2 – Gives a description of the project evolution, from its initial phase towards the actual implementation of the real time simulations;

Chapter 3 – Introduces the operational concept selected for the final PD/3 simulations

Chapter 4 – Describes the process of exploration of operational issues in PD/3

Chapter 5 – Gives a short overview of the PD/3 simulation platforms.

Chapter 6 – Introduces the common approach for training the participants into the simulations.

Chapter 7 – Highlights the difficulties encountered in the final PD/3 integration process.

Chapter 8 – Describes the final PD/3 Demonstrations and the flights trails and highlights the operational findings of the trials.

Chapter 9 – Summarises the essential conclusions of the trials and highlights some of the lessons learnt.

2 THE PD/3 PROJECT PHASES

2.1 DEFINITION PHASE AND MULTISITE ASPECTS

The continuation of the PHARE demonstration programme, following PD/1 and PD/2, with a third large scale real time simulation was elaborated in 1993. The project was initially structured in three steps: Launching, Exploration, and Consolidation.

The project started with a preliminary definition phase. A PHARE Agreement was elaborated on the basis of an outline project plan, which was submitted in mid-1994 to the PHARE Management Board.

The PD/3 Pre-Operational Specification document provided a first description of the operational philosophy and the related research domains to be investigated by PD/3, and the "exploratory scenarios" being used as starting point of the exploratory step.

In order to elaborate valuable candidate scenarios, to specify the required facilities and to build up the corresponding Project Plan during the so-called consolidation step, a first-pass exploratory step was carried out, consisting of detailed analyses based upon the exploratory operational scenarios. The objective was to identify and record the feasibility problems to be solved during the consolidation step.

At the end of the exploratory step the PD/3 Exploratory Project Plan document provided a first detailed description of the project activities based upon the Exploratory Scenarios and an identification of the corresponding problems, difficulties and constraints.

It identified the fact that the project would have to integrate deliverables produced in other PHARE projects (introducing the notion of “PD/3 external projects”)

The concept of Internal Clarification Project was introduced with the objective to refine the Operational Philosophy and define the final demonstration scenarios. A project life cycle was defined including three phases:

- a common definition phase with periodic updates
- a series of large scale demonstrations
- a final consolidation phase of the results obtained through the Internal Clarification Projects and the large-scale demonstrations.

2.2 PROJECT DEFINITION

Considering that this final PHARE demonstration would comprise a five-year project, and given the need to harmonise the views of the projects participants on the detailed contents of the project, a careful method of refining the project description was set-up. In the so-called “Launching definition step” a number of exploratory definitions were made. These concerned the pre-operational specification document and the outline project plan. Six months were used to complete these documents.

In the subsequent “Exploration definition step” a first survey of what was actually feasible in terms of facility requirements, deliverables by the external projects, Internal Operational Clarifications Programme, planning constraints, effort and funding requirements was made. The main deliverables of this step were the PD/3 Exploratory Facility Specification document, including a proposal for updating the External programmes, the description of the programme of Internal Operational Clarification

Projects (IOCP) and the PD/3 Exploratory Project Plan document, including identification of main problems, difficulties and constraints. This step was planned to last nine months.

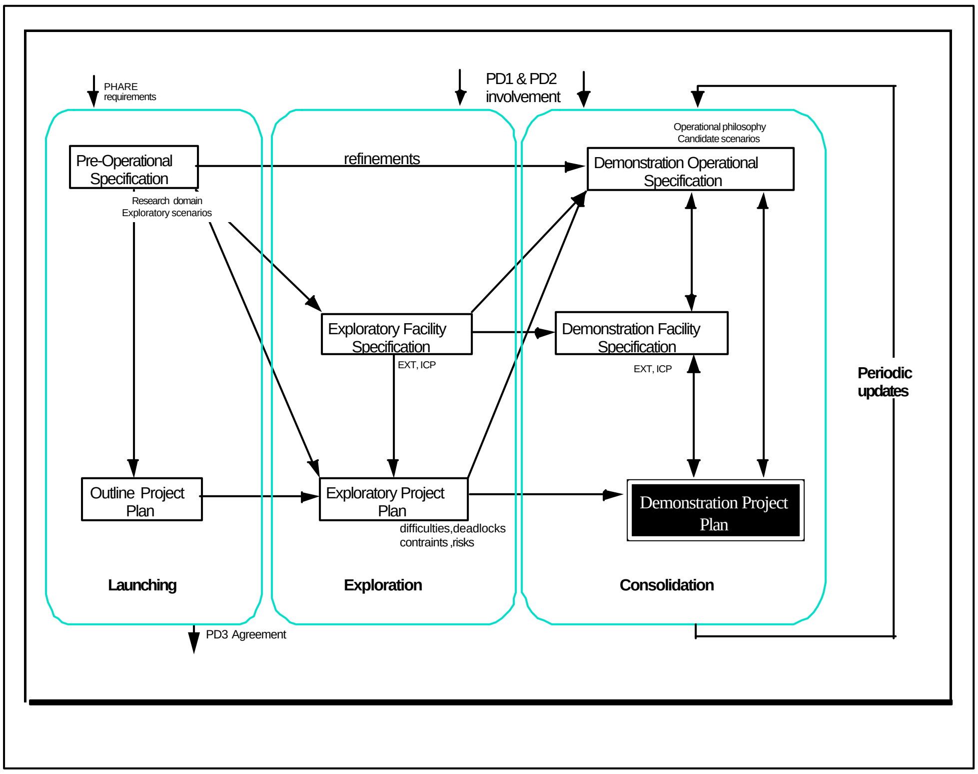

Figure 1: Logic of the PD/3 definition activities

In the third and final step of the project, the "Consolidation definition step", all the information gathered in the first two steps was carefully analysed. Four main documents were finally produced to define and describe the PHARE Demonstration PD/3 as a whole as outcome of the initial definition process:

- The Demonstration Operational Specification document [5] providing the top-level description of the operational philosophy investigated and, as much as possible, demonstrated by PD/3 and the corresponding candidate operational scenarios expected to be simulated during the final large-scale demonstrations.
- The Demonstration Facility Specification document (FAC,[12]) describing the technical, operational and analysis requirements to be met by the simulation environment in support of the PD/3 large-scale demonstrations. As a spin-off from the FAC two other documents emerged, namely the PD/3 Internal Operational Clarification Project programme document [6]and the PD/3 External requirements document [4]
- The Demonstration Project Plan document [3] containing a description of all elements necessary to define the organisation of and to manage the PD/3 project, including the task descriptions, the resource allocations and the project schedule.
- The Management Structure Document whose objective was to clarify the management and working structure internal to PD/3 and in relationship with its PHARE environment.

The third step was completed by mid 1995. In this step, also the information coming from the two preceding PHARE Demonstrations, PD/1 and PD/2, would have to be taken into account.

2.2.1 PD/3 within the PHARE Management structure

With a project duration of five years it is easy to understand that management of the overall PD/3 project was changing over time. This section describes the evolution of the project management and its relation with the overall PHARE programme management.

At the start of the PD/3 project a **Co-ordination Group** (PD3CG) was formed. Each of the partners was represented in this group with their PD/3 local project leader. The project was lead by the overall PD/3 project leader, at the project start provided by CENA, later taken over by EEC, who was also the chairman of the PD/3 Co-ordination Group (PD3CG).

Since PD/3 was 'only' one project in the overall PHARE programme, the PD3CG operated within a management framework which was further comprised of:

- The **PHARE Management Board** (PMB), consisting of high-level representatives of the PHARE partners, taking decisions on a political level concerning the execution of the PHARE Agreement, reporting to the EUROCONTROL Committee of Management.
- The **PHARE Co-ordination Committee** (PCC), chaired by the PHARE Programme Manager, taking decisions on progress of planned activities and priorities between activities and reporting to the PMB.
- The **PHARE Demonstration Co-ordinator**, responsible for the organisation and co-ordination of work between the different PHARE Demonstrations projects (PD/1, PD/2, and PD/3).

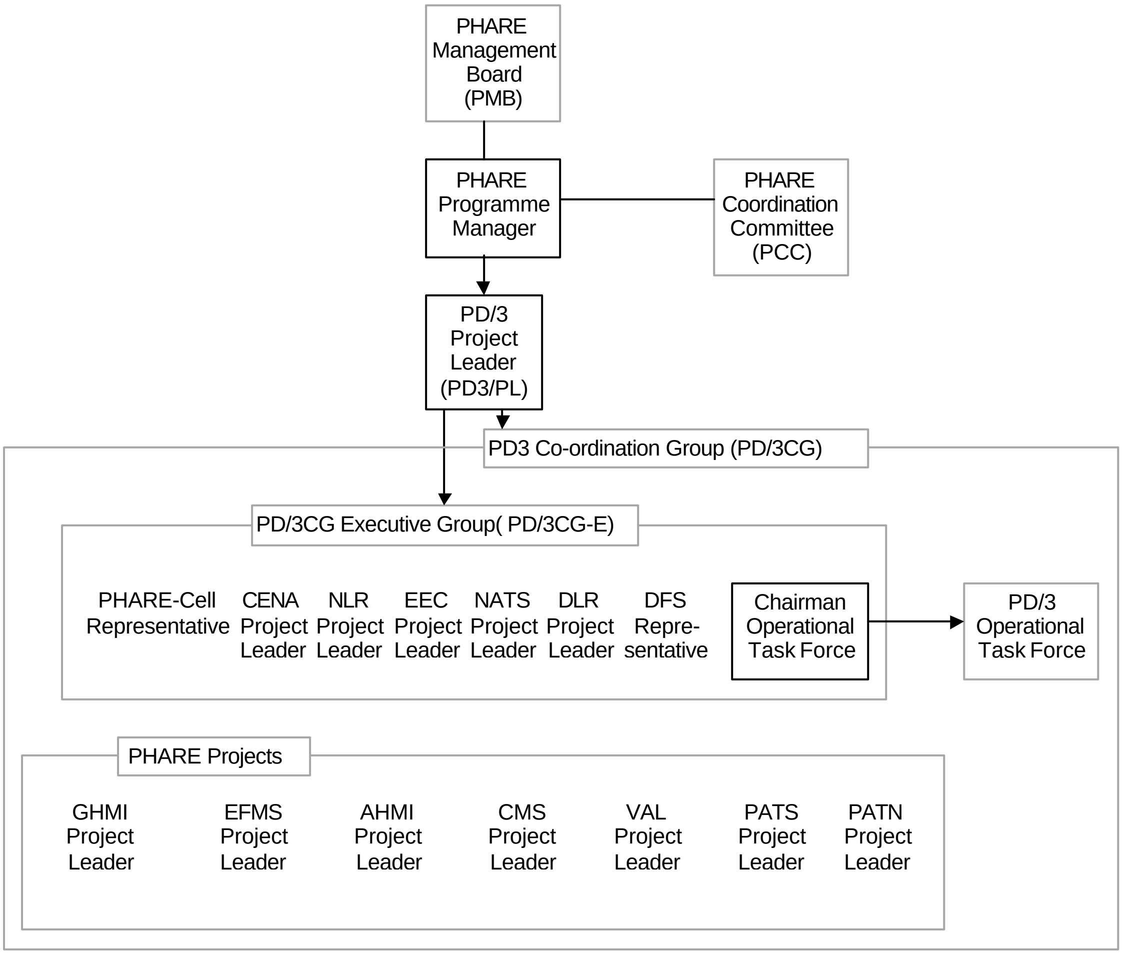

Figure 2: PD/3 Project Management structure

The PD/3 Project Leader was responsible for the organisation and co-ordination of the different tasks within PD/3, and the day-to-day relations with other PHARE projects delivering to PD/3. The PD3CG was responsible for assisting him in the definition and co-ordination of work between the collaborating partners.

Within the PD/3 project definition process it soon was decided that a number of ‘ad-hoc’ task forces would be created to address specific topics.

The first task force that was instantiated was the **PD/3 Operational Task Force** (OTF). It was in charge of elaboration of the PD/3 Demonstration Operational Specification document and of the refining of the corresponding operational scenarios.

The definition of the PD/3 system was initially undertaken by a number of task-forces created by the PD/3 CG.

- the PD/3 Inter-site Simulation Task Force (ISTF): In the original ideas about PD/3, it was the intention to organise one large-scale multi-site real-time ATM simulation to investigate the PD/3 advanced operational concept. A group of technical experts joined in the Inter-site Simulation task Force (ISTF) to investigate all the issues related to this aspect of the project.

- PD/3 Air Servers Task Force: As one of the results of the work of the ISTF, a task force was initiated specifically to address the issue of connecting a number of different Air Traffic Servers in one multi-site simulation.
- PD/3 Data Preparation Task Force: The PD/3 DPTF was organised in July 1995 after the ISTF intermediate report had become available.

These task forces had a limited duration depending on their role and successive orientations of the project.

2.2.2 PD/3 internal management with the Co-ordination Group

The PD/3 Co-ordination Group was tasked with the support of the PD/3 Project Leader in the management of the PD/3 project. It was the forum in which the PD/3 partners discussed the definition of the project, its progress and in which initiatives were taken to control the project. External project leaders participated in these meetings when needed.

2.2.3 PD/3 Operational Task Force

The development of the PD/3 Demonstration Operational Specification was one of the most important activities at the beginning of the project. A team of operational concept experts from the three PD/3 partners was organised to perform the work. This group was called the PD/3 Operational Task Force (OTF).

2.2.4 Project reporting

In order to manage the project, reporting on progress and problems is an important aspect. Within PD/3 this was performed on different levels. It was related to the meetings of the PD3CG and later the PD3EG where the assessment of the project progress was an important agenda item.

As for every project in PHARE, for each of the sites local projects in PD/3, there existed a separate project plan in Microsoft Project ® format. The project reporting was performed with references to these project plans.

On a two-monthly basis the PD/3 site's project leaders were expected to provide a progress report on their local activities. At the PD3CG / PD3EG meetings these progress reports were reviewed and if necessary actions were set out to control further progress.

For those meetings of the PD3CG / PD3EG that were scheduled a few weeks before a PCC meeting, the site's project leaders were also expected to send an updated project plan file to the PD/3 Project Leader and the PHARE Demonstration Co-ordinator. These project plan updates were then consolidated with the plans from the other PHARE projects. This allowed visibility on possible mismatches in planning of deliveries between projects.

The PHARE Demonstrations Co-ordinator would then include information on the difference between the actual plan and the previous version of the plan. The PCC would subsequently assess the result of this consolidated planning and determine whether changes would be needed. As a result actions could be assigned to project leaders, or in case of major problems, issues could be passed on to the PMB.

After the PCC meeting the PHARE Demonstrations Co-ordinator updated all the plans according to PCC decisions and directives and re-distributed them again to the project leaders.

2.2.5 Planning

An elaborate process took place to refine the planning for this project. In the following sections a brief description is given of the various planning documents that have been produced during the project.

2.2.5.1 Outline Project Plan

The PD/3 Outline Project Plan (OPP) was the first real project plan for PD/3. It contained at a high level the first structuring of the project.

2.2.5.2 Exploratory Project Plan

Building on the Outline Project Plan, the Exploratory Project Plan was developed in the Project Exploration definition step.

2.2.5.3 Demonstration Project Plan

The final planning of the PD/3 project was described in the Demonstration Project Plan (DPP) document[3].

2.3 THE SUCCESSIVE REASSESSMENTS.

The initial definition of PD/3 highlighted the high-risk level of the project. Consequently proposals were put forward in the version of the PD/3 Demonstration Project Plan (DPP) delivered in February 1995. A strong monitoring was established and yearly re-assessment reviews corresponding to top-level milestones in the DPP planning were performed. Three successive reassessments took place at the end of 1995, 1996 and 1997.

Several options for re-orienting PD/3, were examined at the 1995 reassessment which considered several simplifications including options such as a centralised demonstration (one site, one demonstrator), three separate demonstrations (one organisation per site) and extension of the Internal Operational Clarification Project programme beyond 1996.

The work plan was revised to give a strong priority to the two first scenarios. The programme of clarification projects (In particular Internal Operational Clarification Projects dealing with operational aspects) had to be streamlined to a bare minimum addressing the three operational aspects of the demonstration:

- en-route multi-sector planning
- human centred approach
- en-route / ETMA interface

Margins for additional Internal Operational Clarification Projects and deeper investigations, notably concerning the third scenario, were preserved, in particular to allow a greater involvement of NATS/DRA and DLR in PD/3 after PD/1 and PD/2 had finished.

3 PD/3 OPERATIONAL CONCEPT

3.1 OPERATIONAL DEVELOPMENTS

In this section a brief description is given of the developments of the PD/3 operational concept. The intention is to describe how the operational concept evolved over the duration of the project.

3.1.1 PHARE Medium Term Scenario 2000 to 2015

Shortly after the beginning of the PHARE programme, a document was written called "PHARE Medium Term Scenario 2000 to 2015" [14]. It contained the first operational scenario description of the PHARE programme. This description was actually a very high level operational concept description, which had insufficient detail to be used for the implementation of an ATM concept simulation system. It did set however the direction in which the PHARE operational concept was subsequently developed.

The key elements described in this document can be summarised as follows:

- A change to a more pro-active environment in which most of the foreseen planning conflicts are eliminated well before they actually become conflicts.
- The use of datalink between aircraft and ground centres and in-between ground centres to dynamically exchange flight planning updates and other data.
- The accurate 4D planning of trajectories by suitably equipped aircraft and by the ATC ground system.
- The use of advanced ATM tools to support the air traffic controllers in their work.
- The application of a layered planning approach, where planning is gradually refined and optimised.
- The use of electronic means to co-ordinate between sectors
- The use of an advanced Ground Human Machine Interface (GHMI) that eliminates the need for paper strips.

3.1.2 PD/3 Operational Concept

The PD/3 Operational Concept was first described in a PD/3 Pre-Operational Specification in June 1994. As part of the project definition steps, this description was further refined by the PD/3 Operational Task Force to become the PD/3 Demonstration Operational Specification[5] which was finalised by March 1995. This final description contained three so-called operational organisations, a baseline, an organisation 1 and an organisation 2. Each of them is described below in more detail. In PD/1 a similar set-up had been defined in order to represent a progressive change in the ATM operational concept. Setting up a simulation schedule, in which each of these organisations would be investigated in comparable circumstances, allowed analysing the operational benefits, which could be expected for each concept.

3.1.3 PD/3 Operational Scenarios

After the Operational Task Force had produced the PD/3 Demonstration Operational Specification, it had to detail the PD/3 Operational Scenarios (see [15] and [16]). The Demonstration Operational Specification was at a too high level to be used for development of the PD/3 simulation system. Many aspects of the interaction between the controllers and the ATC system were just not specified in enough detail. Writing on the Operational Scenarios began early 1995. The first target was to write the internal Operational Scenarios Document (PD/3 IOSD,). In September 1995 the first version of this document was delivered to the PD/3 CG. Each of the partners had mostly provided input to the description of the organisation it was most interested in. The descriptions were therefore not really balanced.

In the 1995 re-assessment of the project the feasibility of success was considered low, given the set-up and status of the project. It was then decided to reduce the operational scenarios from three to two, where the advanced scenario should contain elements from Organisation 0, 1 and 2 of the PD/3 OCD.

3.2 PD/3 CONCEPT OVERVIEW

Extra capacity of the future ATM system is expected from the introduction of new flight management and precision navigation systems, data-link communication, multi-layer planning techniques, and advanced ATC tools to improve air traffic management.

The Experimental Flight Management System (EFMS) developed by PHARE allows the accurate projection of flight trajectories and permit forward, multi-layered planning.

Air Traffic Controllers will be assisted by the provision of a set of advanced tools (PATs) designed to aid the decision making process, permit the timely exchange of data and to improve the aircraft role in the flight planning process.

Communication congestion should be addressed through silent exchange of large amounts of information necessary within the proposed environment by means of data link between air and ground systems.

The Controller and Pilot interactions with the air and ground systems are managed through advanced Human Machine Interfaces (HMI). The Ground HMI have been designed in a consistent manner to implement the concept throughout the PD/3 sites and working positions. The Airborne HMI of the test aircraft involved in the experiments and cockpit simulators has been designed to provide an advanced interface to the EFMS.

An important feature of the Advanced Organisation selected for evaluating the PD/3 concept is that the Air Traffic Controller and Pilot retain central roles. The Human Centred Approach (HCA) is emphasised and the appropriate balance between the system processes and human interest is retained.

The roles of the sector controllers will be changed to allow anticipated planning by the sector planning controller while assisting the sector tactical controller and providing each controller with complementary tasks consistent with the planning time horizon. The three layers of planning and control shall provide for adequate control of the traffic situation at all intervention levels.

The Human Centred Approach, investigated in PD/3, integrates tools designed according to a cognitive engineering approach, which aims at:

- Preserving the controller's interest for the system: he will still be able to cope with the complexity and the variability of the control situations.
- Preserving the controller interest for his job: his creativity to face a new traffic situation and to elaborate relevant solutions. The objective is to avoid moving his activity to a supervision role which will induce loss of skill, poor traffic awareness and inability to cope with unpredicted events.
- Preserving the teamwork by introducing a common representation of the problem situation and computer assistance for an analysis of the traffic situation and a memorisation of identified problems, and the preparation and implementation of solutions.

The Traffic organisation planning philosophy constitutes the core approach of the present PD/3 concept.

The PD/3 Advanced Organisation is based on a rationalisation of previous concepts featuring the Human Centred Approach and a level of more strategic traffic organisation, the Multi Sector Planning. The Multi-Sector Planner performs partial deconflicting while considering strategic objectives.

The management of trajectories in space and in time remains compatible with Air Traffic Controller skill and know-how so as to allow him to exercise his responsibility and his key role in the decision making process.

The organisation of the trajectories in space and time should allow the controller to build and maintain a relevant representation and control of the traffic situation, which is required to perform his task at his level of intervention.

The most advanced process to control air traffic, is 4D control and negotiation. An essential feature of this Advanced Organisation is to apply a fully integrated process of air-ground and ground-ground co-ordinated dialogues via data-link, leading to trajectory "contracts". The high accuracy of 4D prediction and 4D guidance supports enhanced computer assistance and working methods which will lead to increased capacity of the ATM system and enables the Air Traffic Controller team to handle more aircraft simultaneously.

At the same time, consistency and compatibility with different levels of equipment in mixed traffic situations is reached by full compliance of 4D guidance and control with short-term and tactical control processes.

Aircraft not equipped with EFMS are controlled by more tactical and more traditional procedures, using R/T.

Advanced use of ground-ground communication and, related to this, an integrated ATM concept for planning and control is definitely required as complementary added functionality to air-ground integration. Exchange of surveillance and system flightplan data is required to support advanced functionality, e.g.:

- Trajectory prediction capability over a time period of up to 30 minutes.
- Consistency of the working of advanced tools, working over sector and centre boundaries with common representation of problem situation, conflict detection, advisory and conflict resolution capability.
- An advanced system to support executive control and planning activities, and, associated with this, an enhanced system of co-ordination options between team members, sectors and centres.

- Trajectory negotiation capability, exceeding the sector and centre limitations.
- Advanced traffic monitoring options.

The Advanced Organisation includes the concept of multi-sector planning, aiming at providing potential capacity and economy improvements from traffic organisation (trajectory optimisation and tactical flow balancing), early planning unanticipated local congested areas (reduction of complexity)over a larger area and for larger "look-ahead" times. The scope of the planning activities in Multi-Sector is enlarged over a period of 10 to 30 minutes ahead of the current aircraft position.

The role of a Multi Sector Planner will be to offer medium-level strategic rather than tactical solutions to overcome traffic complexity. The Multi-Sector Planner performs partial de-conflicting while considering strategic objectives. Aircraft trajectories will be planned over several sectors.

This Multi-Sector Planner concept combines multi-sector strategic planning with planning at sector level.

Additional elements to be necessarily validated during the experiments while keeping a single advanced scenario include:

- Priority is given to 4D aircraft versus 3D, unless safety is affected, Multi-Sector Planner, Planning Controller and Tactical Controller will perform their tasks accordingly.
- Reduction of the Arrival sequence planning co-ordination process through a simple notification of arrival sequence constraints to the ACC and the en-route sectors
- Flexibility of control is provided to the concerned TMA controllers in introducing the possibility of using early and late arrival time over the Metering Fix.

These early and late arrival times are determined by the applicable fan and/or trombone possibilities in the TMA allowing a tolerance of actual arrival time over the Metering Fix between 0 and 120 seconds.

3.3 ROLE OF THE EQUIPPED AIRCRAFT AND PILOT IN PHARE

Within the PD/3 environment the 4D EFMS equipped aircraft and the pilot are required to operate as a sub-system of the overall ATM system, thanks to air-ground coupling via data-link of airborne 4D EFMS equipment and ground controller working stations.

This integration of air and ground systems enables both the pilot and the controller to elaborate and negotiate accurate trajectories with the aim of:

- providing the pilot with the possibility of flying the aircraft in the most economical way with regard to the uplinked ground constraints
- allowing the controller to anticipate the handling of problems and conflicts up to an extended time horizon (up to 30 minutes).

This co-operative approach is expected to result in a significant improvement of both flight economy and airspace capacity.

ATC has the option of controlling the aircraft either by strategic or tactical methods.

Strategic control involves the use of data-link to obtain proposed detailed trajectories from an aircraft and to issue anticipated required modifications. Tactical control involves the use of R/T to issue short-term clearances from the ground and to obtain responses from the aircraft.

The use of tactical control requires appropriate updates of both the air and ground trajectories in order to prevent « open loops » which preclude any possibility of further strategic control.

The ground is fitted with an aircraft modelled trajectory predictor enabling the controller to uplink to the aircrew proposals which are likely to be flyable in most circumstances. This should avoid the need for extended negotiation cycles.

When a negotiation cycle is finished the ground system is updated by the down linked aircraft trajectory meeting the constraints. This significantly reinforces the accuracy of the ground trajectory prediction capability.

It becomes possible for ATC to propose changes far ahead of the aircraft position and for the aircraft to fly a relatively optimal trajectory.

3.4 AIRCRAFT EQUIPMENT

Equipped aircraft were fitted with the Experimental Flight Management Systems (EFMS), produced as part of the PHARE programme.

The EFMS provides the following overall functionality :

- a data-link facility allowing exchange of complex information between aircraft and ground
- a comprehensive navigation database facility
- the facility to select and edit any relevant trajectory including 4D predictions and required changes from either pilot or ground
- an adequate graphical clearance representation
- a 4D guidance activation function
- a function to monitor the flight trajectory against the current ATC clearance

The EFMS cockpit was be equipped with display and control devices as defined by the AHMI project.

Two classes of device are supported, a Control and Display Unit (CDU) and a Navigation Interface. Either device is capable of displaying the same range of data. The CDU supports the full range of EFMS control and data manipulation possibilities, while the typical Navigation Interface is supporting a « most commonly used » subset of these.

This CDU mirrors the current devices, used as the main interface to the current flight management systems. The format is different and hard buttons are replaced by software buttons.

This interface to the EFMS is considered as a secondary functionality, the primary one being the Navigation Interface.

The Navigation Interface is providing greater functionality than the current EFMS display. The 4D EFMS trajectory can be displayed in terms of horizontal and vertical representation as well as time.

The information can be displayed on two selectable formats, horizontal and vertical, both including time.

« Drag and Drop » facilities are available to facilitate graphical manipulation of routes or constraints.

Inputs to the Navigation Interface can be made via a tracker-ball device and associated buttons.

It is expected that in normal operations this interface will be the primary means of input and output of trajectory management and monitoring.

R/T facilities remain unchanged but the use of R/T is limited to those cases where the Tactical Controller is not allowed to modify or establish a contract via data-link in the available time.

Any direct R/T instruction terminates a contract. The re-entry into data-link control will be announced by the Tactical Controller under the form of a standard message e.g. : « Go direct to Way-point and renegotiate ».

Sign on between aircraft and ground is expected to reassure the pilot that he is on the correct communication channel.

R/T is not used routinely to request or grant clearances on a sector basis since this should normally be handled via data-link.

Frequency change/sign off is expected to be passed via data-link and displayed on the Navigation Interface.

The data-link is assumed to be reliable within the context of the experiment. The operation of the data-link is mostly invisible to the aircrew and to ATC. The data-link is continuously self checking. Any received message is assumed to be correct. No manual monitoring or acknowledgements are required.

3.5 TRAJECTORY NEGOTIATION

The "Contract".

The "contract" is the trajectory, negotiated between air and ground, which the aircraft will fly to some point in the future, if possible up to the landing. The "contract" shall be considered on the ground as the active flight-plan, describing what the aircraft is flying. This trajectory is giving confidence and accurate flight information. The aircraft stores the "contracted" trajectory in its EFMS, and will fly it, 4D compliant, unless an overruling decision of the pilot is required. When "contracted", Ground and Air are working with identical 4D trajectories.

At an airborne level, optimising trajectory prediction and negotiation are based on the scope of a full flight. A trajectory must be continuous and should be viewed in this light as a complete flight either to the destination or to the exit of the area of control.

At the ground level, planning, prediction and negotiation are quite similarly based on optimising a prediction, constraining a trajectory, and negotiating a full flight. However, at the same time, the traditional sectorisation of airspace and the newly introduced transfer of planning authority provides a segmentation of competence on planning and control in space and time. Although this affects in no way the continuity of trajectory prediction, it does affect the negotiation process and the result of it the "contract".

"Sector Contract Approval"

The "sector contract approval" is defined as a section of the aircraft's trajectory that has been agreed by the Tactical Controller. This agreement can only extend to the sector boundary that trajectory, which belongs to the domain of responsibility of the concerned controller. The sector contract approval will be given at "assume control", before entering the sector.

Formalised clearance.

Once a formalised clearance is submitted, or a sector contract approval is received on a trajectory segment, the aircraft is committed to fly that segment of the trajectory, which is part of a down-linked 4D trajectory prediction. The pilot is expected to contact the ground, via R/T, if the approval is not received timely, when the aircraft approaches the next sector.

Stability.

The planning and control process on the ground is based on convergence of planning in time and space. Because 4D "contracts" deserve confidence and because they are accurate over a long planning period, they contribute to the stability of planning. Nevertheless, if re-planning requires this, re-negotiation is possible at all times. Because 4D EFMS-equipped aircraft spend effort in contributing to a stable organisation of traffic, they deserve the priority in problem solving, if not in conflict with an orderly, efficient and expeditious ATC process.

Page intentionally left blank

4 INTERNAL OPERATIONAL CLARIFICATION PROJECTS

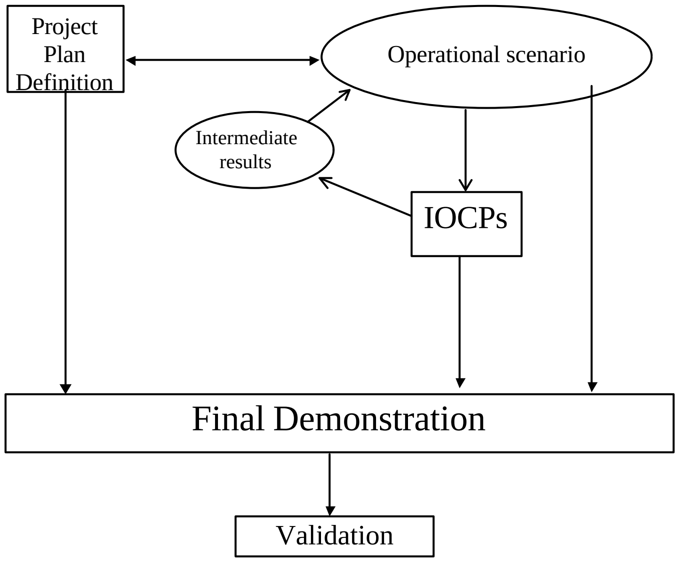

Figure 2 : PD/3 IOCP principles

The Internal Operational Clarification Projects emerged from the Exploratory step of PD/3 launched in April 1994, as illustrated at Figure 2. This initial process identified in Mai 1994 a series of topics to be explored in order to elaborate the operational content of the third PHARE demonstration and including studies in the areas of:

- Dimensioning & Benefit Assessment
- 4D Trajectory Negotiation
- En Route Multi Sector Planning
- Human Centred Approach
- Balanced Task Sharing
- ETMA Pd3 Specifics
- ETMA En Route Interface
- Communication Procedures
- Communication Dimensioning
- Mix Of Aircraft Capabilities

On the basis of the available resources and time, the programme finally converged towards limiting the number of Internal Operational Clarification Projects to three, one performed by each core PD/3 establishment. The selection of these three subjects has been based on the "PD/3 Demonstration Operational Specification" document.

As a result the following Internal Operational Clarification Projects were started:

- "En-route Multi-Sector Planning Procedures" IOCP led by EEC;
- "Human Centred Approach" IOCP led by CENA;
- "ETMA/En-route Interface" IOCP led by NLR.

Each Internal Operational Clarification Project was seen as a sub-project with its own (limited) Operational Specification, Facility Specification, and Project Plan. For each one, a top level description was produced by the performing establishment during the initial definition phase of PD/3.

While the day to day management of each Internal Operational Clarification Projects was under the responsibility of the leading establishment, it was recognised that an operational monitoring of the project was necessary to ensure the consistency of the Internal Operational Clarification Project programme and the exchange of information and views on the concepts exploration. This monitoring task was allocated to the Operational Task Force (OTF).

The results of the Internal Operational Clarification Projects have been reported in references 8, 9 and 10.

At the end of PD/1 it became apparent that the planned participation of NATS in PD/3 could best be performed by means of an additional Internal Operational Clarification Project. This IOCP consisted in further research into the PD/1 results and was conducted by NATS during 1996 and the first quarter of 1997. The results were reported in the PD/1+ final report [11].

Following the 1995 reassessment, the Internal Operational Clarification Projects were integrated in the overall PD/3 planning and extended into 1997. In this way a streamlined project set-up has been achieved in which the various steps of the Internal Operational Clarification Projects coincide with major platform development steps for the final demonstration.

5 THE PD/3 SYSTEMS AT SITES

5.1 ORGANISATIONS

The PD/3 real-time simulations (plural site at CENA, EEC and NLR) included two organisations, baseline and advanced, and suitably structured training exercises.

PD/3 baseline exercises related to the PD/1 and PD/2 reference organisations. This was a “strip-less” organisation which included some basic tools to assist the controller in planning traffic through the sector and also into the approach area.

Traffic mixes were designed to include 4D EFMS-equipped aircraft with traffic samples ranging from a 30% to 70% ratio of 4D EFMS-equipped aircraft.

The Advanced concepts to be evaluated included :

- human centred approach for automation;
- multi-sector planning environment;
- traffic organisation and 4D trajectory negotiation.

5.2 SIMULATION ENVIRONMENT

The airspace simulated comprise parts of Amsterdam TMA, Maastricht upper airspace, Reims ACC, Paris ACC and Roissy Charles de Gaulle TMA, together with TMA and En-route adjacent sectors and multi-sector planning areas.

Airspace data for the reference organisation was taken from the CFMU database as of 21 June 1996.

The advanced organisation used the reference organisation data as start point but evolve in accordance with the PD/3 operational concept to cater for future airspace structures.

The predicted annual traffic growth used in the PD/3 demonstrations considered that by 2005 traffic will multiply by 1.5 on 1995 levels and that demand in 2020 would be multiplied again by 1.5.

To cater for these traffic predictions a series of traffic increments was defined as follows:

	June 1996	1.50	1.75	2	2.25
Baseline	✓	✓	✓	✓	
Advanced	✓	✓	✓	✓	✓

An initial experimental plan was defined on the basis of 14 Runs defined on the above growth hypotheses and taking into account the aircraft mix hypotheses. This plan was later further refined and adapted by the Validation Project.

Traffic (from morning or afternoon)	Traffic from 21 June 96	Traffic +50% (Medium)	Traffic +75% (Intermediate)	Traffic +100% (High)	Traffic +125% (Extra High)
Baseline	✓	✓	✓	✓	
Advanced (no datalink)	✓	✓	✓	✓	
Advanced (30% datalink)		✓			
Advanced (70% datalink)		✓	✓	✓	✓
Advanced (100% datalink)				✓	

5.3 SITE FACILITIES

The local ground platforms used in PD/3 included DAARWIN (CENA), NARSIM(NLR) and ESCAPE (EEC)

These platforms had to provide the capability to integrate the PHARE Advanced Tools and to provide for functionality such as surveillance, flight plan processing and data distribution, as well as ground/ground and ground/air co-ordination capability.

A brief description of the three PD/3 platforms is provided below:

5.3.1 DAARWIN (CENA)

The PD/3 CENA simulation platform is based on the PHARE CMS/PARADISE client/server architecture model. It consists of the following components:

◊ the *core system* DAARWIN which gathers the basic servers and clients of an ATC simulator;

◊ the *tools* which are supposed to be the PHARE Advanced Tools. These tools are plugged into the core-system;

◊ the *GHMI sub-system* gathers four Control Working Positions (TMA, Extended TMA, En-Route and Multi-Sector Planning) and a Supervision workstation;

◊ the *Air-system* composed of :

  * the MASS air-traffic generator;
  * the MCS flight simulator;
  * the real aircraft.

◊ the *communication sub-system* (PATN for operational communications, DIS for simulation communications).

5.3.2 NARSIM (NLR)

NARSIM was built on a UNIX / X-window platform provided by two host computers and several workstations. The actual configuration for a simulation depends on the number of active controllers and pseudo pilots and the number of supporting automatic ATC tools. Six modular, ergonomic and adjustable ATCo working positions were available, each provided with a 29" (2048 x 2048 pixels) colour raster scan display. Touch input devices, track-ball and mouse control devices were available to the ATCo. The simulated aircraft were controlled by pseudo pilots, each equipped with an X-window based interface, controlling up to 15 aircraft each. A computer-controlled radio telephony system was used for communication between ATCo and the pseudo pilot.

The functional elements of existing or future ATM systems were incorporated as separate functional modules including:

- Air traffic simulation
- Multi-sector simulation
- Radar simulation
- Meteo simulation
- Arrival manager
- ATCo interface
- Datalink simulation

These modules were tied together by NARSIMS's advanced Client/Server middleware. On top of this middleware, a distributed debugging tool, the supervisor, was built. The supervisor allowed events and data to be traced throughout the simulator, monitored the internal and external states and offered the possibility to start and stop the modules dynamically.

5.3.3 ESCAPE (EEC)

The ESCAPE platform consisted in 5 separate components, the Ground subsystem performing the Flight Plan Data Processing, the Mass subsystem simulating the aircraft traffic, the Audio Lan system dealing with Radio and Telecommunications. The controller working positions themselves were part of the Eons subsytem and the whole architecture was based upon a Common Platform using a CORBA middle-ware to provide inter-client communication.

The ground system included the Flight Plan Data Processing System (FDPS) of ESCAPE. Its components were true implementations of Air Traffic Management functions.

The objective of the Ground system was to provide a complete model of the current air traffic situation and to predict the future development of the scenario. The system was made of various components dealing with specific areas of ATM functionality, these interacting to produce the data which is then displayed on the controller working positions.

The Multi Aircraft Simplified Simulator (MASS) provided pseudo pilot positions, each handling up to 32 aircraft, with a maximum of 500 aircraft flying simultaneously. This configuration was being enhanced to provide, in particular for PD/3 :

- Advanced navigation including 4D EFMS
- Ground-Air datalinks consistent with operation protocols
- Response to detailed weather scenarios

Each MASS position provided a pilot with a display enabling them to select aircraft and to issue orders to aircraft as well as to communicate with the controllers via the Audio-LAN.

The EONS (Eurocontrol Open And Generic ATC Graphics System) had the objective to allow the rapid building of Air Traffic Control situation displays. It provided the tool kit of ATC conceptual objects (eg. track, flight plan, conflict etc.) and associated graphical objects that could be combined and instructed to interact as defined by the simulation needs.

The common Middle-ware Platform consisted of a CORBA based 'middle-ware' for ATC simulation and experimentation. A first project dedicated to the development of this middle-ware resulted in a prototype that was used in ESCAPE for the preparation and run of PD/3.

5.4 PHARE ADVANCED TOOLS

The PHARE advanced functionality had to be integrated in each of the local platforms. This included the following set of tools.

TP	Trajectory Predictor
FPM	Flight Path Monitor
CP	Conflict Probe
PS	Problem Solver
AM	Arrival Manager
DM	Departure Manager
CT	Co-operative tools
TLS	Traffic Load Smoother
NM	Negotiation Manager

5.5 THE PD/3 GROUND HUMAN MACHINE INTERFACE (GHMI)

The human interface for PD/3 was design by a team of experts from the GHMI project in order to cover the operational concept elaborated by and in co-operation with the PD/3 Operational Task Force.

This interface included and integrated number of interface tools and their associated windows including :

System Message

General Tool Box

Radar Plan View Display (PVD)

PVD Tool Box

Message In/Out / Notification

Look Ahead Display (LAD) Control Panel

Tactical Load Smoother (TLS) Complexity Map

Activity Predictor Display (APD)

Stack Manager Window (VVD)

Arrival Manager Display (AMD)

Conflict Risk Display

Aircraft Advisories Display

Multi-Sector Planner Notepad

Vertical Aid Window (PEL / XFL)

PD/3 HIPS : Trajectory Support Tool (TST)

Sector Inbound List

Sector Exit List

Radar Label

Departure Manager Display(DMD)

Each Controller Working Position, depending on the airspace and the controller role concerned, was designed to be equipped with a suitable sub-set of these tools/windows.

5.6 AIR SYSTEM CAPABILITY

The air system facilities used in PD/3 simulations were based on each site air system software (MASS and NARSIM) and had to fulfil the following requirements:

1. to simulate EFMS equipped aircraft with 3D and/or 4D navigation capability;

2. to simulate a 4D trajectory calculation algorithm. This could be based on existing EFMS trajectory calculators or on a more simple general purpose trajectory predictor.

3. to provide datalink message exchange capability;

4. to cater for voice and data link equipped aircraft;

5. to support the transfer of flying authority between air facilities and flight simulators and/or trials aircraft;

6. the capability to handle at least 20 aircraft per pseudo pilot position.

5.7 RESEARCH AIRCRAFT

It was planned to include demonstrations of the full air-ground trajectory negotiation capability during the PD/3 simulations. Since research aircraft were likely to be influenced by external constraints that could affect measured exercises (actual weather, technical problems and real traffic control intervention), it was considered that these aircraft would only participate in non-measured exercises. This meant that specific exercises needed to be defined for research aircraft participation.

Because the ground elements of PD/3 were split across three sites, each focusing on different phases of flight, the following scenarios were used for aircraft or flight simulators participating at a particular site:

CENA Site	***Scenario:***	En-Route inter-sector co-ordination in the departure phase (TMA, ACC, en-route)
	Aircraft:	DERA BAC 1-11
EEC Site	***Scenario:***	En -Route - Multi-Sector Planning (SID exit gate to STAR arrival gate)
	Aircraft:	No aircraft participation – Use of the MCS (cockpit simulator)
NLR Site	***Scenario:***	En-Route ETMA interaction in the arrival phase (en-route, ACC, TMA)
	Aircraft:	NLR Citation

6 AIR TRAFFIC CONTROLLERS' PARTICIPATION AND TRAINING.

Air Traffic Controllers participation into PD/3 was gained through a common advertisement process, initially in the direction of the Air Traffic Services world-wide, together with publication of programme descriptions on the World-Wide-Web.

It was recognised from the experience gained through other PHARE demonstrations that particular attention had to be given to the participants training. In particular, the Air Traffic Controllers had to be made aware of the experimental nature of the demonstrations, as compared to other simulations which are more closely related to the current infrastructures.

It was agreed that a common training approach had to be applied by all PD/3 sites and a programme was elaborated in close co-operation between the PD/3 sites and the training experts of the GHMI project.

Global objective of the PD/3 Training project was therefore to design, develop, conduct and evaluate the PD/3 training for the Controller Working Positions, which were to be simulated in PD/3: Multi-Sector Planner, En Route Planning Controller, En Route Tactical Controller, Arrival Sequence Planner, Arrival Tactical Controller, Departure Planning Controller and Departure Tactical Controller and 3 sites: NLR, EEC and CENA.

The PD/3 Training was designed and developed by means of an Instructional Systems Design and Development Model including 4 phases:

- Instructional Analysis (WHAT should be learned?)
- Instructional Design (HOW should it be learned?)
- Instruction Development (Production)
- Instruction Evaluation (What is the value?)

The PD/3 Training had the following objectives:

1) Grasping the PD/3 concept
2) GHMI-familiarisation
3) Learning the procedures (airspace + rules, working methods)
4) Tools-familiarisation
5) Integration of knowledge and skills
6) Skills speeding-up (i.e. building up the required speed of the skills, by varying traffic density and complexity)

For the planning the following preliminary training organisation was taken as a starting point:

1. *Standalone PD/3 System (Scenarios):* tools, procedures, integration, Site & Role specific
2. *Distance Learning: C*oncept, GHMI introduction, Common roles
3. *Computer Based Training (PC): concept, GHMI, tools, procedures, Common & Role specific*

4. *Linked PD/3 System (Scenarios):* reinforcement, practice features, speed, Site & Role specific

- **Distance Learning:**

It was learned from PD/1 and PD/2 that a great deal of the training time was needed to grasp the concept. Therefore it was decided that a preparatory phase would be introduced in order to reduce the overall training time. This preparatory phase consisted in providing general information about PD/3 and an introduction in the PD/3 concept and GHMI to participating controllers before they arrived for the trial.

- **CBT:**

Computer based training, with explanations (e.g. instructions & self-discovery screens), graphics, animations, interactions (e.g. page turning, GHMI), trainee monitoring system (e.g. selftests, feedback and adaptive branching). This part was designed to contain the common knowledge and skills to be learned and forms the basis for the standalone and linked systems. The advantages of CBT were to reduced training time (40-60% versus instructor led), to improved retention of information (consistent delivery, individualised instruction), to reduce simulator trainer requirements, improved motivation (interactive), self-paced.

The CBT did not attempt to build the PD/3 system with full functionality on a PC. It only addressed the part-tasks (e.g. how to operate a tool, what is the function of a tool).

- **Standalone PD/3 system:**

Simulation environment based on the PD/3 system, with freeplay activities in different traffic scenario's, without pseudopilots. The Controller would be using the system for air traffic control and learn the procedures (method of controlling). This phase was introduced to reinforce the CBT sessions.

- **Linked PD/3 system:**

Full simulation environment as in the final demonstrations, with pseudopilots, headsets, time pressure in different traffic scenario's. Further task integration and reinforcement of the learned knowledge and skills in the CBT and standalone simulation takes place. Besides that, the skills for using the PD/3 system was meant to be speeded-up to a required level, by varying the scenario's (traffic density and occurring events/problems) from light to heavy.

- **Setting up the training programme.**

A common approach to develop the training package was applied as far as possible. The Eurocontrol Institute of Air Navigation was involved in the design of the CBT; their recommendations were applied to the final design and production of the CBT package by the Training Team. The CBT package was developed at NLR using the Authorware software.

A common definition of the Controller Handbooks and associated training material was elaborated, although each site training programme and materials had to be adapted to the specific scope of each simulation.

7 THE PD/3 INTEGRATION PROCESS

7.1 PLATFORMS – PATS - CMS

The approach taken at the different sites to conduct the Internal Operational Clarification Project programme largely influenced the final integration process.

At the time when the initial exploratory simulations started, the EEC real time simulation platform was evolving towards a more versatile environment. The PD/3 team of the EEC had to use a different platform, based on a rapid prototyping facility, to elaborate the first investigations into the Multi Sector Planning concept. This was imposing a subsequent final integration onto a main demonstration target system, which would have to be capable of providing the performance required by a large-scale simulation.

CENA and NLR had selected to progressively integrate the tools and develop the required interfaces on a CMS like environment. NLR, in particular, totally linked their integration to the progressive availability of PHARE tools, into a continual integration process.

However by end 1996, the PHARE Advanced Tools integration at NLR was encountering technical difficulties. At this stage, it was necessary to fully adapt the NARSIM architecture to the target architecture but the functionality of the PHARE tools was insufficiently mature. CENA was not experiencing difficulties of that nature at this stage but delays were due to the HMI development for Internal Operational Clarification Projects.

A configuration control mechanism for PHARE Advanced Tools was established on the basis of available material in the context of PD/2; this mechanism was felt to provide the basis for the final integration of the PD/3 version of the tools. PHARE Advanced Tools requirements compatibility with PD/3 Operational Requirements had still to be ensured. However, the priority given to PD/2 was significantly delaying adequate co-ordination with the PHARE Advanced Tools projects. Strong emphasis was put on the need to provide a consistent event model of the PHARE Advanced Tools environment and necessary meetings were scheduled.

In the area of the Common Modular Simulator project, a revised CMS management structure was introduced to improve co-ordination through the creation of a User group. The set-up of a proper version control mechanism and change control procedure was required.

Simultaneously by the end of 1996, it was felt necessary to reinforce the monitoring of the PHARE projects through the PD/3 Co-ordination Group so that arising problems and risks are identified quickly, this was facilitated by the introduction of configuration control and problem reporting procedures. This mechanism was further drastically improved by the introduction of a Problem Tracking System directly accessible on-line through a web interface. The Problem Tracking System was extensively used at weekly Configuration Control Board meetings, which were held through teleconferences from mid-97 until the final demonstrations.

In October 1997, the finalisation of NM and TP deliveries were delayed by the identification of additional changes required for compatibility with CMS version 2.1. In order to minimise as far as possible any further impact on tools deliveries and consequently on integration plans, an approach was taken, which consisted in freezing as much as possible the evolutions of CMS while the the effort of tool developers will be made available to assist at sites for final integration when required, priorities being agreed between PHARE Advanced Tools and PD/3 project leaders.

The GHMI development approaches at the various sites were reviewed in early 1997; some commonality of development were envisaged on the basis of the EONS system developed at the EEC to design the Controller Working Positions of the real time simulator.

The NLR decided to adopt the EONS system for Controller Working Position development and consequently shared developments with EEC.

The implementation of the Multi-Sector Planner position at CENA was envisaged using the elements developed by EEC providing a transcoding layer to CMS would be written on the basis of the ESCAPE API.

The difficulties encountered in the development of the PD/3 EONS software at the EEC in the end of 1997 introduced unrecoverable delays in the NLR integration, which led to successively to postponing their pilot phase and later to the cancellation of the initially planned main phase. A similar consequence was the drop of the multi-sector aspects at CENA.

7.2 VALIDATION

Following the lessons learned during PD/1 and PD/2, the final PHARE Demonstration further considered to apply the general recommendations provided by the PHARE Validation project.

The methodology was thoroughly reviewed by the Validation Group and was discussed with the PD/3 partners during dedicated workshops. These discussions resulted in a refinement of the validation objectives and the revision of the methodology to cover them.

This common work further allowed to define the low level validation objectives specific to each site demonstration.

A workshop held mid 98 gave the opportunity to consider possible reduction of controller interventions, which were then reviewed by the GHMI design team in close relation with the Operational Task Force chairman; this resulted in a compromise solution for the negotiation and Co-ordination by exception principles.

7.3 GHMI

For PD1 the specifications for the Baseline and Advanced HMIs had been prepared by EEC and reviewed by the GHMI group. For PD2 a Design Team had been established from the GHMI group, led by DLR with NLR and EEC participation. A similar approach was taken for PD3, where EEC led a larger design team with CENA DLR and EEC participation. The PD3 Design Team worked in close collaboration with the Operational Task Force and PHARE Advanced Tools groups. This definition was strongly linked to the elaboration of the operational scenarios and to their initial exploration through Internal Operational Clarification Projects

All three activities relied heavily on contributions from PHARE Advanced Tools and the software implementation teams.

In order to clarify the status of changes to be applied to the evolving PD/3 GHMI specification, the evolution requests applying from Version 2.1 and leading to the delivery of the following version were submitted formally to PD/3 CG for approval and were monitored via the configuration management procedure and system which had been introduced for tools and platforms.

7.4 PATN

A set of data-link applications had been defined in the context of the multi-site definition of the PD/3 project.

Data Link requirements were still not completely finalised by the end of 1996 due to the necessity to appropriately match the selected priority applications with the PD/3 needs

- A Downlink Aircraft Parameters was available
- The Trajectory Negotiation application had to be redefined on the basis of PD/1 data exchange formats in order to use data structures more adequate to the full PATN environment.
- A Position Reporting application was defined, which was implemented differently by the PD/3 sites depending on their needs for flight trials.

While DLCRD protocols were established, dialogue data for the trajectory negotiation application required extensive discussions between the NM, TP and EFMS teams.

Several intermediate PATN platforms were used both to provide tests means for the PATN deployment and integration tests, and in order to provide PATN demonstrations. The PATN integration process is fully described in the PATN final report in [24].

Page intentionally left blank

8 PD/3 TRIALS

8.1 PD/3 TRIALS AT CENA

8.1.1 CENA trials schedule

The CENA Pilot Phase was planned from 16 Mar '98 to 27 Mar '98 and was successfully completed. Two sessions of trials were planned for the CENA Main Demonstration Phase : 1 11 May '98 - 5 June '98 and 8 June '98 - 26 June '98.

Work on the CENA platform prior to the main phase was dedicated to the introduction of corrections resulting from the Pilot Phase. Performance of the platform had to be improved. High-level traffic samples ran with good response time. The HMI response time however required additional improvement.

The CENA data recording system was tested and equipment provided by NATS to perform workload assessment were integrated.

CENA decided in the light of Pilot Phase input and from previous experience to use a two-screen CWP. An ancillary screen was used to display the Profile Window and Message-In and Message-Out windows.

CENA final integration in view of the main phase progressed according to plans, which gave confidence about the feasibility of the main phase.

The CENA 1st session of the main phase was actually started by training the controllers. No specific issue was identified during this session, which was based essentially on standalone positions. The preparation of the platform for the main trials was satisfactory.

Some difficulties remained to be solved concerning the controller working position structure and PHARE Advanced Tools integration, which could not be based solely of PHARE versions of the tools.

A major issue in the integration process at CENA was the integration of the PHARE Advanced Tools Trajectory Predictor (TP) which was delayed and could only be achieved for the second series of runs.

The two sessions of the main phase were conducted without major problems. The experiments were coupled with flight trials of the BAC1-11 during specific runs.

Each session of the CENA PD/3 experiments followed an overall programme including:

- 5 days training using standalone and classroom
- 1 day training with real system and pseudo-pilots
- 8 days runs
- 1 day general debriefing

The training was satisfactorily accepted by the controllers. The first session showed that the ability to use the tools was acquired on the 3rd day run.

About 40 measured runs were made through these experiments.

8.1.2 CENA results outline

In the Departure & ETMA context the following was found:

- All Workload indicators showed an increasing perceived workload on both Planning Controller and Tactical Controller positions due to the introduction of advanced organisation.
- Nevertheless, these results proved to be more obvious in Planning Controller as an effect of transferred workload (planning activities).
- Frustration and Time pressure factors proved to be of great influence on the overall feeling of perceived workload for Planning Controller and Tactical Controller.
- Though introduction of DL equipped aircraft did not prove to really influence the perceived workload, when introduced in a high proportion, it seemed to bring the most positive impact on the Tactical Controller positions.

The ability to suitably handle traffic volumes in a Departure/ETMA context was assessed in relation to the number of separation infringements. This was however limited by the difficulty to fully use the STCA alerts. While the time to cross TMA and ETMA reduces the number or the duration of infringements increase with the introduction of advanced organisations. A majority of controller was doubtful regarding the safety aspects in case of 100% 4D EFMS equipped aircraft traffic. According to them, the conditions to well intervene in emergency on these aircraft were not fully met.

A significant majority of controllers agreed that it was difficult to handle the traffic with the given task partitioning in the Advanced organisations whereas no real trend was shown for this question regarding the Baseline organisation. But, the nature of the PHARE real time demonstrations cannot allow to firmly conclude on safety aspects and their bearing on capacity estimates. The identified safety issues are matters for further research.

Concerning Quality of service, In the Departure environment, the single introduction of advanced tools allowed the aircraft to spend less time in the others sectors (TMA and ETMA). When introducing both the advanced organisation and Data Link there was a significant diminution of the time spent per aircraft in sectors when considering them together. However, several factors had interfered during the trials. Further investigation devoted to the Quality of service should involve entire trajectories to allow assessing such parameters as arrival time.

The introduction of the layered task sharing, showed specific issues for Planning Controller/Tactical Controller Co-operation. While, in baseline, Planning Controller and Tactical Controller shared the same space-time environment regarding traffic awareness, the controllers became frustrated by the lack of co-operation allowed by the system in advanced organisations. The feeling of insecurity in Tactical Controller’s mind was largely induced by the lack of efficient support from the Planning Controller. The Planning Controller felt a huge mental demand to build again and update his knowledge of the traffic when he sometimes had the possibility to focus his attention back on the current traffic within the sector. Therefore he was rarely receptive enough to adequately assist the Tactical Controller. Compared to what happened within Baseline organisation, a lack of co-operation resulted from the rare verbal communications between them. This introduced a so-called ‘operational gap’ which also induced strong feeling of frustration for the Planning Controller.

When traffic increased Planning Controller was not available to provide tactical assistance. This suggested further need to study Planning Controller and Tactical Controller roles.

The first investigation of an advanced departure management tool, despite the limitations of its test environment, proved that DM is full of promises. However this initial DM implementation showed rigidity to controller intervention. The Departure Planning Controller / Tactical Controller appreciated the clear and synthetic view of pre-departure traffic pattern. Combining sequencing functions and trajectory functions in DM was a really interesting orientation. However planning actions on pre-departure aircraft proved much less credible. Controllers perceive the DMD (Departure Manager Display) as an essential co-operation tool for the actors of departure sequencing (controllers and AM-DM co-ordination). The sequencing functions of DM would deserve to be deeper investigated in enriched simulation environments.

The Co-operative Tools approach, applied in an advanced planning environment, appeared positive for the en route planning activity. However the Planning Controller strategy had to be adapted to traffic load, when the APD became saturated. The approach was either to refer to the radar image or to focus on the APD with the risk of loosing mental picture. Advisory labels appeared as an efficient link with the TEPS tool since it displayed a synthetic view of what the Planning Controller prepared on non-equipped aircraft trajectories. The question was raised of the adequacy of the APD as co-operative support for conflict matters in the context of a layered task sharing of Planning Controller / Tactical Controller. A major part of problems presented in Tactical Controller's APD concerned those left by Planning Controller. They had to be resolved in emergency. Tactical Controller was focusing on radar image. As a consequence the problem situation presented to the tactical controller appear of limited utility. Mechanisms have been proposed to address co-operation in this context.

The experimental environments used throughout PHARE did only allow identifying possible trends for workload acceptability in the advanced organisations. The extensive analysis of workload components has shown to lead to beneficial HMI design adaptations. It was also clearly shown, through other PHARE simulations run in parallel of PD/3 (PD/1+, PD/1++) that advanced tools are likely to perform better with an advanced airspace and route philosophy, adapted to multi-sector planning and user-preferred direct routings.

Trajectory Negotiation appeared inadequate for tactical action TN (response time / complexity) - and was most appropriate for planning and dynamic re-routing.

Arrival Management in its full implementation would need to be further evaluated through measured trials.

Advanced Planning, aiming at reducing traffic complexity, showed great potential for trajectories optimisation and conflicts resolution in comfortable conditions. Trajectory support, which is strongly linked to this concept, might be really advantageous.

There would be a number of pre-requisites to effectively apply advanced planning:

- a clear sharing of tasks has to be ensured between Planning Controller and Tactical Controller to allow a clear and mutual awareness of trajectory editions.
- some controllers in ETMA and En-Route sectors were strongly disturbed by the simple fact that two controllers could work in the same time on the same aircraft trajectory.

The shared planning authority, as a real complementary notion to the advanced planning concept, appeared very fragile as regards controllers' acceptance.

It would need early display of incoming traffic has to be effective so that the early handling by the planning authority can be of real interest. It may require redesigned airspace for optimum results.

Trajectory negotiation appeared as a positive concept since it could lead to a much more accurate forecast and a significant decrease in R/T occupancy. The trajectory support has shown a great potential since it could allow tuned and enriched operational exchanges with the pilot.

However the use of data-link procedures did not appear to cope with tactical activities. The negotiation procedure will always require a minimum delay to be accomplished because of human implication (controllers and crew) and consequently must be carefully implemented in some control contexts.

Improvements in general system response times as well as GHMI dialogues optimisations like horizontal and vertical trajectory editions would allow much more precise and consistent assessments in further experiments.

A detailed account of the CENA experiments operational findings is given in Ref. [20].

8.2 PD/3 TRIALS AT EEC

8.2.1 EEC trials schedule

The PD/3 Pilot Phase was conducted between 30 March and 3 April 1998. The PD/3 platform was not available at this stage so that the objective of the pilot phase was limited to providing training for the participating controllers in the PD/3 concept, the interface and the various tools associated with the advanced organisation. The training was intended to comprise classroom and CBT sessions supplemented by 'hands-on' explanations using the PD/3 simulation platform. For this specific aim, a three-day training course had been conducted by INSTILUX for the PD/3 simulation team covering the issues associated with coaching techniques. Both the controllers and simulation team considered the CBT as being of limited usefulness and a number of suggestions for improving key topics were made by the controllers.

The exposure of the controllers to the actual simulation environment was limited to two short sessions. In both cases the baseline system was employed. Due to problems associated with the communication system and poor system response times, these sessions served only to familiarise the controllers with the layout of the simulation room and some of the simulation hardware. During these two periods, it was not possible to supplement any of the material presented during the training sessions with genuine operational demonstration.

Following the PD/3 Pilot Phase, a number of improvements to the CBT package were incorporated by NLR. The new version was sent to each of the participating controllers in the weeks prior to the main phase, as well as an instruction book describing each main tool and its method of interaction as well as the PD/3 concept and associated controller roles

By mid April 1998, the EEC platform integration was 50% complete. Integration was running in parallel on two platforms: the main simulator and a testbed.

Performance problems, which had been experienced at the start of the EEC integration, were improved by installing new graphics cards. In a similar way, new workstations were leased and introduced on the target platform.

The EEC Baseline Organisation and a first build of the advanced organisation were installed onto the main platform end of April.

Training material was elaborated on time for the main phase and taking into account the elements brought by the initial pilot/training phase. Training guides were made available to all partners.

Due to HMI unavailability, the main demonstration could not be started with a full system test.

The main phase of the EEC PD/3 Demonstration actually took place on 4 May '98 - 29 May '98 and was completed without measured runs, using the baseline and some advanced course plus baseline hands-on simulations. System having been available late, debugging of the baseline continued. Despite a number of unsuccessful runs, controllers were in a position to progressively control traffic samples. Errors and inconsistencies were corrected as far as possible in between runs and after the sessions.

The number of inconsistencies was decreased by successive improved deliveries. The traffic was brought from 75% to 100% increase. EEC continued to experience difficulties with the baseline system. Essentially in the area of co-ordination, colour states of the aircraft.

The advanced organisation continued to be integrated and tested outside of the simulation runs and despite extensive testing performed over week-ends was considered as not in a satisfactory state to be used.

Problems affecting radar label states and co-ordination were identified; this blocked progress due to the effort required in trying to define the problems and their resolution.

A network saturation problem was traced to TP - AM interaction and use of the FPM. This meant that Air and Ground systems lost synchronisation and exercises had to be stopped.

EEC PD/3 priorities were directed at completing the integration and testing, and working with the participants to better understand the tools and concept. The last week of the main phase was planned to provide testing of trajectory edition and eventually 4D negotiation but it was not expected that measured runs could be performed. It had to be considered that the EEC main phase has failed its objective to provide measured exercises. Despite the problems, controllers were able to provide feedback and comments. These comments were gathered and analysed and the results were presented in

8.2.2 EEC indicative results on Multi-Sector Planner

There were too many limitations in the EEC system behaviour to allow a full evaluation to be performed of Multi-Sector Planner aspects. However, controllers on the advanced environment provided a number of interesting comments.

The TEPS was considered as potentially useful although the tool appeared complex initially. It should take more into account the distance and angle of the subject aircraft predicted track. The issue of responsibility of solving conflicts for other sectors was raised.

Complexity zones used in multi-sector planning tools appear as a notion difficult to understand. It raised the questions of what aircraft to modify to reduce complexity and would require a fast information update to be usable.

The Look Ahead display would need conflict information to be provided contrary to what initial experiments had shown and a better integration to allow fast identification and modification of aircraft involved. The Sector load window includes complexity curves, which are considered of interest. The usefulness of the sector traffic window would have to be reassessed in effective Multi-Sector Planner scenarios.

This feedback has to be considered with care but has led to a number of recommendations for further studies which are part of the EEC PD/3 report (Ref [21])..

8.3 PD/3 TRIALS AT NLR

8.3.1 NLR trials schedule

The schedule of the NLR trials suffered successive alterations. A main phase session was run as an integration exercise between 25 May '98 - 5 June '98. A continuation trail was further defined an ran at the end of 1998.

The initial integration of the PD/3 system at NLR was delayed by the need for EEC to provide successive update of the EONS software following the identification by EEC of deadlocks in this system. Adaptations to improve the system performance were also required.

The first series of simulations in May 1998 was directed at testing with the assistance of the participants, but no measured runs could be performed. Five air traffic controllers and five pseudo pilots were available for one week of intensive system integration tests. These tests consisted of running the baseline and advanced systems, using the traffic samples developed for the main trials. The system integration test was used to train both pilots and Air Traffic Controllers in using the system. A stand-alone versions of the PD/1 system was used to train the Baseline system operation. Although an advanced demonstration run was made, the system still had insufficient functionality to be used operationally in a simulation. Due to the numerous and significant further changes, the integration could not be completed, reducing any chance to run the advanced organisation. NLR took the option to focus on demonstrating its capabilities to run well organised, measured trials using its PD/3 baseline system. On June 5th NLR had finished its trials in the framework of PD/3. At that moment a two week measured exercise had taken place. In this exercise only the baseline system was used.

8.3.2 PD/3 continuation trials at NLR

The assessment of the situation of PD/3 at NLR lead to the initial conclusions that:

- Some modifications were required to the set-up of the system. In particular the TMA would need to be manned with two tactical controllers to realistically simulate the concept.
- Development of a new advanced Ground Human Machine Interface would be required to perform a real PD/3 trial. This development was not expected anymore from EEC.
- Proper development of this Ground Human Machine Interface would take quite some time and effort.
- Any final trial would therefore take at least till after the summer of 1999 to be performed.

However, the idea was also put forward that there might be an option to develop the advanced Ground Human Machine Interface on the basis of further developments of existing PD/1 software.

The PD/3 review team tasked a small team of experts to identify the feasibility of this approach, which resulted in the following plan:

- Development of an advanced PD/3 Ground Human Machine Interface on the basis of PD/1 software, completed by mid October 1998.
- A pilot trial of the new system in November of 1998.
- A main trial in February of 1999.
- A final report in June 1999.

EUROCONTROL accepted the feasibility of this proposal and contracted experts from NLR, CGP, NATS and DERA to perform the work up to and including the pilot phase.

This PD/3 continuation project started in August,1998 with the development of the advanced Ground Human Machine Interface. A detailed plan had been made of the work to be performed. The progress of the work has been closely monitored since that date and reported on a weekly basis to EUROCONTROL.

In the mean time it became apparent that the EUROCONTROL Agency would not have the funding to continue the project up to the main experiment in February 1999. It was therefore decided that the NLR pilot trial would become (partly) a public demonstration. NLR planned to perform a number of real pilot experiment sessions and reserved a few days to present the system to a selection of invitees.

8.3.3 NLR PD/3 Continuation Scenario

The baseline organisation for the NLR final PD/3 trial was the same as for the PD/3 final demonstration. It was decided to make a number of changes to the advanced PD/3 operational scenarios.

The basis of the concept was to close the planning loop. This was done by generating an accurate trajectory prediction for every flight. For aircraft that do not have data-link equipment, the planned trajectory was only available in the ATC system since R/T was not suitable to transfer the whole trajectory at once. The ATC system would therefore advise the air traffic controller on clearances that were required to keep the flight as close as possible to its planning.

The concept included the use of User Preferred Trajectories, which allowed operators to select their optimal flight profiles and routes. RVSM was introduced for the whole airspace above FL290. The planning of inbound aircraft was supported by an advanced *Arrival Manager* tool, optimising the arrival sequence for every landing runway in use.

8.3.4 NLR indicative results

No measured trials were performed in PD/3 at NLR. During the continuation trial demonstrations questionnaires were however filled out by the participating controllers giving an indication of the feedback of these controllers on a series of topics.

A majority of the controllers were convinced that the trajectory display functionality was useful in resolving conflicts and the colours used were easy to understand and use. The Trajectory Support Tool (TST) turned out to be useful in simplifying co-ordination and was easy to use for the majority of the controllers.

Most controllers managed to handle the increased traffic with the tools provided but also showed that not everyone felt in control of the system at all times. The ability to use User Preferred Routing contributed considerably to the perceived increase in systems capacity. The HIPS and conflict probe-based conflict detection algorithms were not always in line, which caused confusion. It is expected that the application of the concept in a busy TMA environment needs further attention, in particular concerning the role and tasks of the tactical controllers.

Most controllers appreciated label colour coding. The planning status of an aircraft was clear for all but one controller. The presentation and the quality of the conflict information of the conflict risk display (CRD) can be improved.

When accessing flight details, controllers preferred selecting the aircraft label as opposed to the Conflict Risk Display or Sector Inbound List (SIL). The HIPS was used frequently.

On the use only few reactions have been gathered, which were not very consistent. Although there seemed to be some support of the Arrival Manager through the time line presentation it was clear that significant further work is required on this item.

The statement that the system would allow controllers to manage 2010-2015 traffic levels was confirmed by a majority of the controllers. Remarks were made however quoting issues like the handling of non 4D EFMS-equipped traffic, incorporating realistic (longer) data link delays and the general requirement for more extensive evaluations.

All controllers agreed that a higher percentage of 4D EFMS and data-link equipped aircraft will increase the system's performance. On the other hand all controllers agreed that should non-standard and/or emergency traffic have been simulated, this would have lowered the maximum traffic capacity shown in the experiment.

The full report on the NLR exercises is presented in ref [22].

8.4 AIRBORNE PROGRAMME ASPECTS

8.4.1 EEC Airborne Evaluation

The EEC airborne evaluation trials were conducted in the Multi Aircraft Cockpit Simulator (MCS) environment. It was only possible to link the Multi Aircraft Cockpit Simulator to the ground system for technical tests while the ground was running the baseline system. Despite this limitation, the evaluation was conducted using an emulation of the ground system. The experiment focussed on the planning and negotiation task of the pilot not-flying and the monitoring task of the pilot flying. The participants constituted a good mix of pilots of various origins; they provided significant feedback [25]).

8.4.2 CENA Flight trials

The CENA PHARE Airborne demonstration with the DERA **BAC1-11** live aircraft took place on the week 2-5 June 98. It was a specific exercise within the whole CENA PD/3 demonstration. Its objective was to show to visitors the capabilities of the PHARE air/ground integration. With two flights per day, visitors attended the BAC1-11 onboard demonstration on a half day and the CENA ground system on the other half day. Around 50 visitors of the ATM community were taken onboard during three demonstration days.

The main points presented during the airborne demonstration were:

- the use of Experimental Flight Management System capabilities to manage 4D routes and to carry out air/ground 4D trajectory negotiations
- the establishment of an air/ground connection through the PHARE Aeronautical Telecommunications Network using the INMARSAT satellite
- the use of datalink applications before take-off and during the flight:
- Controller-Pilot Data Link Communication- for the position reporting
- Controller-Pilot Data Link Communication- for the frequency change
- Trajectory Negotiation for the negotiation of 4D trajectories

Though a lot of technical difficulties occurred (presence of a local radar near the runway, poor quality of service of satellite network…), it has been possible to demonstrate several times the trajectory negotiation between the Athis-Mons platform and the aircraft.

8.4.3 NLR Test flights

In the time leading up to the PD/3 experiments at NLR the PHARE Aeronautical Telecommunications Network, Experimental Flight Management System and Airborne Human Machine Interface teams had to overcome several problems with the end to end integration and testing of all systems. The most significant problem in the end was the configuration of the satellite sub-network. Similar problems were observed at CENA, involving the BAC1-11.

Finally on the 3rd and 4th of June, some successful flights were made. The NLR **Citation** II was equipped with the Experimental Flight Management System, the Airborne Human Machine Interface and a PHARE Aeronautical Telecommunications Network end system. Via the satellite sub-network it was connected to the PHARE Aeronautical Telecommunications Network ground end system that was connected to the NARSIM facility. Using the Position Reporting application, the aircraft could be tracked on the ATC simulator. Trajectory messages were down-linked using the 4D Trajectory Negotiation application but the transmission delay via the satellite sub-network was unacceptably long. The full protocol of the Trajectory Negotiation application could not be tested due to the problems with the satellite connection.

In the cockpit the advanced Airborne Human Machine Interface was displayed to the pilots. As no coupling with the auto-pilot existed, the pilots were flying the aircraft 'manually' following the 4D guidance information generated by the Experimental Flight Management System. This indicated that even aircraft without an auto-pilot coupled to the FMS can accurately fly 4D trajectories.

9 CONCLUSIONS & LESSONS LEARNED

9.1 BASIC CONDITIONS

General conclusions and lessons learned from PHARE as a whole are presented in the PHARE Final Report (Ref. [23]). This chapter presents the view as seen from the PD/3 project.

Although the PHARE Demonstration 3 did not achieve the full validation of the gate to gate concepts, the available results have given clear indications for the subjects of further research and development.

The elaboration of the operational concept has put the emphasis on a " Human Centred Approach " with the introduction of Traffic Organisation and a Layered Planning concept.

The basic conditions of the final demonstrations have to be kept in mind while considering the operational findings:

- The exploration of the concept did not cover airport aspects.
- The demonstration were not aimed at investigating the concept under exceptional conditions (meteo, recovery procedures);
- Furthermore the test systems were not pre-operational systems and had limitations in "some" system aspects.
- The initial objective assigned to PD/3 which consisted in testing the end to end scenario in an interconnected environment appeared not feasible and had to be reverted to a set of individual simulations, therefore interaction between the various systems were not considered.
- The maximum rate of 4/D flight management equipage was generally held at 70%, recognising the fact that it is highly unlikely all airline operators will find it economical to be equipped with this avionics fit.
- The use of trajectory negotiation by strategic operators as it was intended through the Multi-Sector planning concept was not fully explored. This area seemed promising as trajectory negotiation could be better anticipated.

Drawing the lessons learnt from previous experiments, an emphasis was put on training the participants to the experiments and this approach was generally well received by controllers at all sites during the PD/3 trials.

9.2 OPERATIONAL FINDINGS

The PD/3 demonstrations explored a large variety of aspects linked to the introduction of air-ground integration. In spite of the variety of the experiment environments, some commonalties of finding can be identified:

The feasibility of the air-ground integration was demonstrated in a series of flight trials either linked to the ground demonstrations or run independently, which used a set of applications (including the 4D-Trajectory Negotiation) and the Airborne Human Machine Interface. The connections were established using the PHARE Aeronautical Telecommunications Network, through the satellite sub-network.

Trajectory negotiation appeared as a positive concept from the controller perspective as well as it could lead to a much more accurate forecast and a significant decrease in R/T occupancy. The Trajectory Edition approach was considered as useful in resolving conflicts and in simplifying co-ordination. Trajectory Negotiation appeared inadequate for tactical action TN (response time / complexity) - and was most appropriate for planning and dynamic rerouting.

Effects of transfer of workload to the Planning Controller were identified. The introduction of data link brought the most positive impact on the Tactical Controller positions. The extensive analysis of workload components has indicated beneficial HMI design adaptations, confirming findings of other PHARE demonstrations.

The introduction of the layered task sharing in the departure and en-route environment at CENA, showed specific issues for Planning Controller/Tactical Controller Co-operation, referred to as an 'operational gap'. This suggested further need to study Planning Controller and Tactical Controller roles.

The introduction of advanced departure management appeared as an essential co-operative aspect between the actors of departure sequencing.

The integration of 4D arrival management with en-route traffic handling appeared feasible and did not introduce extensive co-ordination requirements. Stability of the arrival sequences was achieved gradually well before the aircraft approached the airport, resulting in a very efficient flow of traffic into the TMA.

The Co-operative Tools approach, applied in an advanced planning environment, appeared positive for the en route planning activity. Complementary mechanisms to address co-operation between Planning and Tactical controllers will have to be adapted to make the co-operative tools approach acceptable in high workload conditions.

It was clearly shown, through other PHARE simulations run in parallel of PD/3 (PD/1+, PD/1++) that advanced tools are likely to perform better in different airspace and route structures. The ability to use User Preferred Routing contributed considerably to the perceived increase in systems capacity. It also appeared in PD/3 that redesign of airspace might also be required for an optimum application of the concept of shared planning authority

Multi-Sector Planner aspects need to be further assessed considering that Advanced Planning, aiming at reducing traffic complexity, showed great potential for trajectories optimisation and conflicts resolution in comfortable conditions.

9.3 LESSONS LEARNED

9.3.1 Changing scope

PD/3 was clearly recognised from its initiation as a large project requiring risk management to be strictly applied. As part of the risk reduction measures, the need for small size calibration exercises, embedded into the project as scoping studies was identified from the start of the project. These were seen as means to refine the technical and operational issues as well as increasing the feasibility of the project. However, the decision to streamline this exploratory programme was taken too late in the project and a further reduction in scope was necessary. The approach initially taken in PHARE towards technology demonstrations bent the emphasis towards large scale integrated simulation programmes which had finally to be reduced to single simulations.

9.3.2 Relations with other PHARE projects

Most of the PHARE projects had already started before PD/3 and had set their own courses, which were not necessarily strictly in line with the PD/3 requirements. This had not become visible until PD/3 tried to integrate all the work of PHARE. The harmonisation of the project deliveries for PD/3 led to an effort overhead.

9.3.3 PD/3 Operational Scenario

The elaboration of a detailed set of scenarios and procedures was necessary to satisfactorily implement the concept investigations. This elaboration was led in very tight co-operation between the Operational Task force and the Ground HMI Design Team, in an iterative process, which converged towards the specification of an harmonised controller interface for the PD/3 demonstration. It was however necessary to limit the spectrum of options to be explored to a smaller range of options merging the pure de-confliction approach with the human centred approach.

A similar convergence had to be obtained in harmonising the airborne view of the concept with the controllers view.

9.3.4 Advanced tools for PD/3

Several factors had to be taken into account to reach the convergence of the PHARE Advanced tools and Common Modular Simulator projects towards the implementation of the PD/3 scenarios:

- Complexity of the projects, especially the PHARE Advanced Tools being developed by different establishments;
- The lack of an overall system view including tools and simulators,
- The lack of common knowledge about the capabilities of the tools whose development had been started earlier than the PD/3 design.

The principles of the Common Modular Simulator as a unifying medium to provide final integration of the demonstration components were retained through the definition of the modules interfaces which were kept consistent through configuration control for the final integration. The adaptations at each site necessitated additional effort. The review process required to harmonise the PD/3 PHARE Advanced Tools with the operational requirements only reached an adequate iteration level at a critical time of the project. Sufficient effort should have been dedicated earlier in the project to allow a team approach to that definition.

9.3.5 PHARE Management

A stronger empowered management should have been enforced from the beginning of the project. The initial management structure was close to the structure adopted for the initial PHARE demonstrations: a gathering of the establishments involved directly in PD/3The project had initially only horizontal co-ordination links with the other PHARE projects. Stronger links should have been implemented earlier if the PHARE Working Groups and management bodies to ensure a faster convergence of the various projects. Redundancy was often felt between the higher PHARE management structures and the project structure in particular PD/3. This was addressed by reducing the duration of PCC meetings to leave technical discussions to project (PD3) level.

9.3.6 PHARE spirit

Despite the number of difficulties, to which was added the need to complete the PD/3 demonstrations in a stringent time frame, the kind of partnership specifically allowed by the PHARE programme has most probably been the reason why most partners continued to actually focus on the research topics and tried everything possible to run the demonstrations. In addition to providing initial threads towards the validation of the future ATM, the PD/3 demonstrations have allowed the partners to consolidate their simulation environments for further use in testing future concepts.

10 GLOSSARY, LIST OF ACRONYMS

3-D	three dimensional (latitude, longitude and altitude)
4-D	four dimensional (latitude, longitude, altitude and time)
ACC	Area Control Centre
AHMI	Airborne Human Machine Interface
AM	Arrival Manager (PATs)
AMD	Arrival Management Display
APD	Activity Predictor Display
API	Application Programming Interface
APP	Approach Centre
ARR SP	ARRival Sequence Planner
ARR TC	ARRival Tactical Controller (INI and ITM)
ASTF	Air Server Task Force
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATMOS	Air Traffic Management and Operations Simulator
ATN	Aeronautical Telecommunication Network
BAC 1-11	DRA Civil Avionics trials aircraft XX105
CAA	Civil Aviation Authority (UK)
CBT	Computer Based Training
CDG	Charles-de-Gaulle Airport
CENA	Centre d'Etudes de la Navigation Aérienne (France)
CFMU	Central Flow Management Unit
CGP	CGP Ltd (UK)
CLW	Communications list window
CM	Context Management, a D/L application
CMS	Common Modular Simulator
CORBA	
CP	Conflict Probe (PATs)
CPDLC	Controller Pilot Data Link Communications, (an air-ground D/L application)
CRD	Conflict Risk Display
CRNA	Centre Regional de la Navigation Aérienne

CT	Co-operative Tools (PATs)
CWP	Controller Working Position
D/L	Data Link
DA PC	Departure ACC Planner Controller
DA TC	Departure ACC Tactical Controller
DAARWIN	Distributed ATM Architecture based on RNAV Workstations Intelligent Tools and Networks
DAP	Downlink Aircraft Parameters, an air-ground D/L application
DCT	Demonstrators Co-ordination Team
DEP	DEParture controller
DEP PC	DEParture Planner Controller
DEP TC	DEParture Tactical Controller
DFS	Deutsche Flugsicherung GmbH
DIS	Distributed Interactive Simulation
DL	Data Link
DLARD	Datalink Application Requirements Document
DLCRD	Data Link Communication Requirements Document
DLR	Deutsche Forschungsanstalt für Luft- und Raumfahrt (Germany)
DM	Departure Manager (PATs)
DMD	Departure Manager Display
DNA	Direction de la Navigation Aérienne (France)
DPTF	Data Preparation Task Force
DRA	Defence Research Agency (UK)
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme
EATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference
EEC	EUROCONTROL Experimental Centre
EFMS	Experimental Flight Management System
EPP	Exploratory Project Plan
ER PC	En-Route Planner Controller
ER TC	En-Route Tactical Controller
ERATO	En-Route Air Traffic Organiser
ES	Exploratory Scenario for PD/3
ETMA	Extended Terminal Manoeuvring Area
FAA	Federal Aviation Administration (USA)
FAC	Facility Specification

FDPS	Flight Data Processing System
FMS	Flight Management System
FPM	Flight Path Monitor (PATs)
HAW	horizontal assistance window
HIPS	Highly Interactive Problem Solver (PATs)
IOCP	Internal Operational Clarification Project
ISTF	Inter-site Simulation Task Force
LAD	Look Ahead Display
LFV	Luftfartsvæsen (Denmark)
MASS	Multi Aircraft Simplified Simulator
MATS	Manual of Air Traffic Services
MCS	Multi Cockpit Simulator
MSP	Multi-Sector Planner
MSS	Multi-site Simulation Specification
NARSIM	NLR ATC Research Simulator
NATS	National Air Traffic Services Ltd (UK)
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (Netherlands)
NM	Negotiation Manager (PATs)
NRF	NATS Research Facility
ODS	Operational Display Systems
ORG	Operational ORGanisation used as demonstration scenario
OSD	Operational Scenarios Document
PARADISE	Prototype of an Adaptable and Reconfigurable ATM Demonstration and Integration Simulator Environment
PAT	PHARE Advanced Tool
PATN	PHARE Aeronautical Telecommunication Network
PATs	PHARE Advanced Tools
PC	Planning Controller
PCC	PHARE Co-ordination Committee
PD	PHARE Demonstration
PD/1	PHARE Demonstration 1
PD/2	PHARE Demonstration 2
PD/3	PHARE Demonstration 3
PEL	Planned Entry Level

PHARE	Programme for Harmonised Air Traffic Management Research in EUROCONTROL
PC	PLanning Controller
PMB	PHARE Management Board
PRT	PHARE Demonstration Review Team
PS	Problem Solver (PATs)
PVD	Plan View Display
R/T	Radio / Telephony
SID	Standard Instrument Departure Route
STAR	Standard (Terminal) Arrival Route
STCA	Short Term Conflict Alert
STNA	Service Technique de la Navigation Aérienne (France)
TEPS	Trajectory Editor and Problem Solver
TLS	Tactical Load Smoother (PATs)
TLX	(NASA) Task Load Index
TMA	Terminal Manoeuvring Area/ Terminal Control Area
TN	Trajectory Negotiation
TP	Trajectory Predictor (PATs)
TST	trajectory support tool
VAL	VALidation project
VAW	Vertical Assistance Window
VVD	Vertical View Display
XFL	Exit Flight Level

11 REFERENCES

[1] PD/3 Operational Scenarios Document (Volume 1);NLR, EEC, CENA;DOC 97-70-04;Jan-97

[2] PD/3 Operational Scenarios Document (Volume 2);NLR, EEC, CENA;DOC 97-70-08;Mar-97

[3] PD/3 Demonstration Project Plan;PD3EG;DOC 95-70-01;Jul-97

[4] PD/3 Demonstration Facility Intersite Simulation Requirements Specification;ISTF;DOC 96-70-20;May-96

[5] PD/3 Demonstration Operational Specification;CENA, EEC, NLR;DOC 95-70-02;Mar-95

[6] PD/3 IOCP Programme;CENA, EEC, NLR;DOC 95-70-12;Jul-95

[7] PD/3 Demonstration Facility Specification;P.Latron;DOC 95-70-09;Apr-98

[8] PD/3 IOCP Programme: En-route Multi Sector Planning Procedures;EEC;DOC-97-70-15;Aug-97

[9] PD/3 IOCP Programme: Human centred approach ;CENA;DOC 97-70-18;Nov-97

[10] PD/3 IOCP Programme: En-route / Extended TMA Integration;NLR;DOC 98-70-06;Jan-98

[11] PD/3 IOCP – NATS: PD/1+ Trial Report, DOC 97-70-10, April 1997

[12] Demonstration Facility Specification document vs 4.2 DOC 95-70-02, Apr 98

[13] PHARE DEMONSTRATION 3 continuation project description, NLR Memorandum VL-98-022, 15 September 1998, NLR

[14] "PHARE Medium Term Scenario 2000 to 2015", Issue 1 (Draft), Eurocontrol, July 1990

[15] "PD/3 Operational Scenarios Document", Volume 1, PHARE/NLR/PD3-1.1.3.2.2/OSD1;2.2

[16] "PD/3 Operational Scenarios Document", Volume 2, PHARE/NLR/PD3-1.1.3.2.2/OSD2;2.0

[17] PD/3 Operational Scenarios Document (Volume 1) NLR, EEC, CENA DOC 97-70-04

[18] PD/3 Operational Scenarios Document (Volume 2) NLR, EEC, CENA DOC 97-70-08

[19] PD/3 Demonstration Project Plan PD3EG DOC 95-70-01

[20] CENA PD/3 Final Report C.Chabrol,JC Vigier,J.Garron,D.Pavet, DOC 99-70-01, Volume 2 of 4, Mar-99

[21] EEC PD/3 Simulation Final Report, A.Marsden, D.Hudson, E.Jeannot DOC 99-70-01, Volume 3 of 4, Mar-99

[22] NLR PD/3 Final Report, W. Post, DOC 99-70-01, Volume 4 of 4 Aug-99

[23] PHARE Final Report, M. Van Gool, H. Schroeter, Eurocontrol, DOC 99-70-09, July 1999

[24] PHARE ATN, Final Report, DOC 99-70-03

[25] PHARE Airborne Programme Final Report, July 1999

All PHARE public reports are available on the internet at the PHARE www site:

http://www.eurocontrol.be/projects/eatmp/phare/index.html

Internal reports are available on request at EUROCONTROL Headquarters.