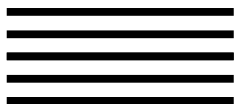


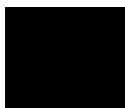
PROGRAMME FOR
HARMONISED AIR TRAFFIC
MANAGEMENT RESEARCH
IN EUROCONTROL



DOC 94-70-02



EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION, **EUROCONTROL**



PD1 OPERATIONAL SPECIFICATION

PHARE/CAA/PD1-2.3/OPS;1



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REVISION HISTORY

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Dec. 1993	Draft Version 1	Re-structured version of the Operational Specification document for review by PRT/2.	M van Gool (PD Coord) P Jorna (GHMI) J-R Velten (CMS) P Huet (PD3) F Schick (VAL) J Reichmuth (PD2) E Petre (PATs) R M Gingell (PD1)
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1. SCOPE

This document provides the top-level description of the operational concepts to be evaluated by PD1 and the overall scenario that will be used to determine quantitative and qualitative data to validate the concepts. This document forms the output of tasks PD1-1.2 and PD1-2.3.

PD1 is a collaborative venture between the PHARE partners which is being hosted by the CAA at DRA Malvern. The collaboration takes the form of consultancy to tasks led by CAA and deliverables to PD1 from other PHARE projects. Details of the effort and deliverables to PD1 are given in the "Outline Project Plan for PHARE DEMO 1 (PD1)", reference 1.

There are major deliverables to PD1 which have a direct impact on the development of the facility, the scenarios to be executed and the detail of the operational procedures, these are as follows:-

- the GHMI specification which is being delivered by the PHARE GHMI group
- the experimental validation concepts and measures which are being derived by the PHARE Validation and Tools group
- the computer assistance tools which are being provided by the PHARE Advanced Tools (PATs) group

The facility to support the PD1 will be complete when these groups have delivered and the hosting site team has performed the integration and testing. At this stage the definitive operational procedures will be complete. The detailed operational procedures will be provided in the PD1 Operational Scenarios document, reference 2.

Where reference is made to Related Documents the version and issue of such documents will be the most recent specified in the Configuration Control document (see related Documents)

2. INTRODUCTION

Today's ATC system in Europe (and elsewhere) is at times unable to handle the demands made upon it. Flow restrictions imposed to safeguard the system from overload often lead to delays during peak periods. In many of the less busy areas in Europe, the required capacity goals can be achieved by well-proven technology and procedures, representing "best current practice". In the busiest areas, however, the scope for increasing capacity through existing ATC methods and technology is limited. Although developments as regards airspace, routes and sectorisation undoubtedly must and indeed will be pursued, changes in the technology and the process of ATC must also be envisaged if capacity and productivity gains are to be secured. The limiting factor in the present ATC system is the capacity of the controller. A means has to be found by which the controller can be enabled to handle a larger number of aircraft in a given airspace without significant increase in workload. This will have to be achieved whilst maintaining or improving system safety.

One proposed method is by providing automated assistance to both the Planning and Tactical Controllers and, by the application of data links for air to ground communication. The provision of automated assistance to the controller will support him in the resolution of conflicts and in planning efficient use of the airspace. The introduction of datalink to communicate between the airborne systems and ground environment will remove some of the current communication load from the controller and in addition enable the use of onboard data to improve the precision of the ground system's aircraft model for track prediction and conflict prediction. In providing such support and removing from the controller and pilot certain executive tasks by means of direct computer to computer communication, it is necessary to ensure that the tasks removed from the pilot and controller are those which are best executed by computer and those which remain are those best executed using the flexibility and adaptability of human skills. The areas where computer support is expected to yield improvements are the accurate predictions of future aircraft profiles, the analysis of potential options for the resolution of conflicts and sequencing of aircraft for optimum use of airspace and runways. These, together with the monitoring of flight execution, could provide a support environment that would allow a safe reduction in aircraft separation. To achieve this, detailed aircraft performance data, meteo condition information and criteria concerning aircraft operational requirements would need to be made available to the ground environment using data link communications. These proposals raise a number of questions concerning the resulting division of responsibility and tasks between the aircraft and the ground. Proposed solutions for this responsibility sharing will need to take into account, *inter alia*, the relatively small bandwidth of the available data links and the differing strengths and weaknesses of the human and the computer. It is to answer some of these questions that the developments within the PHARE Programme have been proposed.

PHARE, has developed the necessary ground and airborne tools that will be initially evaluated as individual components. To evaluate the performance of the resulting air/ground integrated ATM system, a series of real time simulations entitled "PHARE Demonstrations" will be executed in which the proposed options will be compared and recommendations made on the contribution such automated support could make to the future European ATM system. The PHARE Demonstrations will be initiated by separate simulations of the en-route and TMA environments that will take place concurrently.

This simulation is run in the context of a demonstration of some of the PHARE tools.

3. OBJECTIVES OF THE SIMULATION

3.1. GENERAL

- Validation of the EATCHIP concepts
- Partial definition of the description of the future Air Traffic System concepts

3.2. SPECIFIC

PD1 is intended to demonstrate the quantitative capacity and productivity change resulting from the introduction of computer assistance tools and data link facilities. The environment will be en-route airspace in the timescale circa 2000 simulating several en-route sectors and emulating entry and exit conditions at TMA sectors. It will be hosted by CAA at DRA Malvern. It is envisaged that the controller's basic roles of planner and tactical will not be subject to major changes but assistance will be provided in terms of "computer assistance tools" and datalink. The new elements will support the definition of a new control method, still based on current practices, but improved and adapted to provide "look ahead" facilities and conflict free planning. The fact that ATC will be performed in a similar manner to today's operation (i.e. maintaining the basic roles of planner and tactical together with the same sectorisation) will considerably reduce the number of options to be considered. The sectors to be used for the simulation will be the UK New En-Route (NERC) sectors 10 and 11.

These objectives can be summarised as follows:

1. To determine the effect on controller workload and traffic throughput of the introduction of computer assistance tools from the PATs programme.
2. To determine the effect on controller workload and traffic throughput of the increasing proportion of 4D FMS aircraft with full duplex datalink.
3. To gain a degree of controller approval for the introduced computer assistance.

4. ORGANISATIONS

PD1 is a real-time simulation comprising three "organisations". The major concepts which characterise the different organisations are as follows:-

- the introduction of advanced computer assistance tools to assist the Planning Controller with his task of planning conflict free trajectories through his sector.
- the increasing use of datalink functionality and the resulting increased information content

PHARE Demonstration 1 will simulate a two-man sector operation applied to the NERC sectors 10 and 11. Each sector will have a Tactical Controller (TC) and a Planning Controller (PC).

There will be no paper flight strips, the information that is normally held on the flight strips will be presented to the controllers electronically. The information will be presented to the controllers in a number of ways using various HMI techniques.

PD1 will comprise of a number of experiments that will test the effect of the introduction of computer assistance tools and of increasing proportions of 4D FMS equipped aircraft to the traffic sample on the controller workload. Initially a Reference System will be developed which will provide a baseline against which to measure the effect on performance of the introduction of computer assistance tools, 4D FMS aircraft and datalink facilities.

There will be three "Organisations":-

- ORG 0 Reference Baseline organisation
 - o up to 10 minutes of planning anticipation (as in current systems);
 - o mixed aircraft population (as foreseen for year 2000) with 3 flow rates (low, medium and high);
 - o current controller roles of Planner and Tactical will be maintained;
 - o derived from ODID III (Organisation 2) which operates without paper flight strips and with simple tools based on 10 minute look-ahead (e.g. Conflict Risk Display, Entry/Exit Aids);
 - o airspace NERC sectors 10 and 11 with adjacent feed sectors.
- ORG 1
 - o up to 20 minutes of planning anticipation;
 - o mixed aircraft population (as foreseen for year 2000) with 3 flow rates (low, medium and high);
 - o computer assistance derived from the PATs 2000 Toolset;
 - o controller methods reflect the extended look ahead and conflict free planning;
 - o downlinked data is available from aircraft;
 - o airspace as ORG 0.

- ORG 2
 - o as for ORG 1 in terms of computer assistance and control methods;
 - o mixed aircraft population (as foreseen for year 2000) with 3 flow rates (low, medium and high). 30% and 70% ratio of 4D FMS equipped aircraft introduced in traffic samples; a live aircraft, the DRA (Bedford) BAC 1-11 will be included in this Organisation.
 - o two-way datalink capability within pre-defined protocols, 4D trajectory and ATC clearance exchange;
 - o airspace as ORG 0.

To support these organisations two software systems will be constructed to run on the same platform, one to support the reference organisation and the other, an advanced system incorporating the advanced computer assistance tools, to support the subsequent organisations. All the facilities required for ORG's 1 and 2 will be provided in the advanced system build. The essential differences in the advanced organisations (ORG's 1 and 2) relate to operational procedures and the inclusion of 4D FMS aircraft in the traffic sample therefore the underlying platform can remain the same. By not including 4D FMS aircraft in the traffic sample for ORG 1 those aspects of the facility relating to the handling of 4D FMS aircraft will not be invoked.

4.1. THEMES FOR COMPARISON

The experimental evaluation themes relate to the organisations as follows:-

ORG 1 versus ORG 0:

- measurement of the impact of new computer assistance tools in an environment comprising aircraft equipped with datalink capability, albeit limited to downlinking of information to be used to improve the accuracy of the ground based trajectory prediction.
 - o measurement of the effect of increased "anticipation time" to assist the Planning Controller in his task of planning conflict free trajectories through his sector.
 - o measurement of the effect of proposing an "anticipated solution" by the Planning Controller to the Tactical Controller.

ORG 2 versus ORG 1:

- measurement of the effect of introducing 4D FMS equipped aircraft together with full-duplex datalink into the scenario
 - o measurement of the impact of datalink trajectory and clearance exchanges on sector throughput.
 - o measurement of controllers communication load.

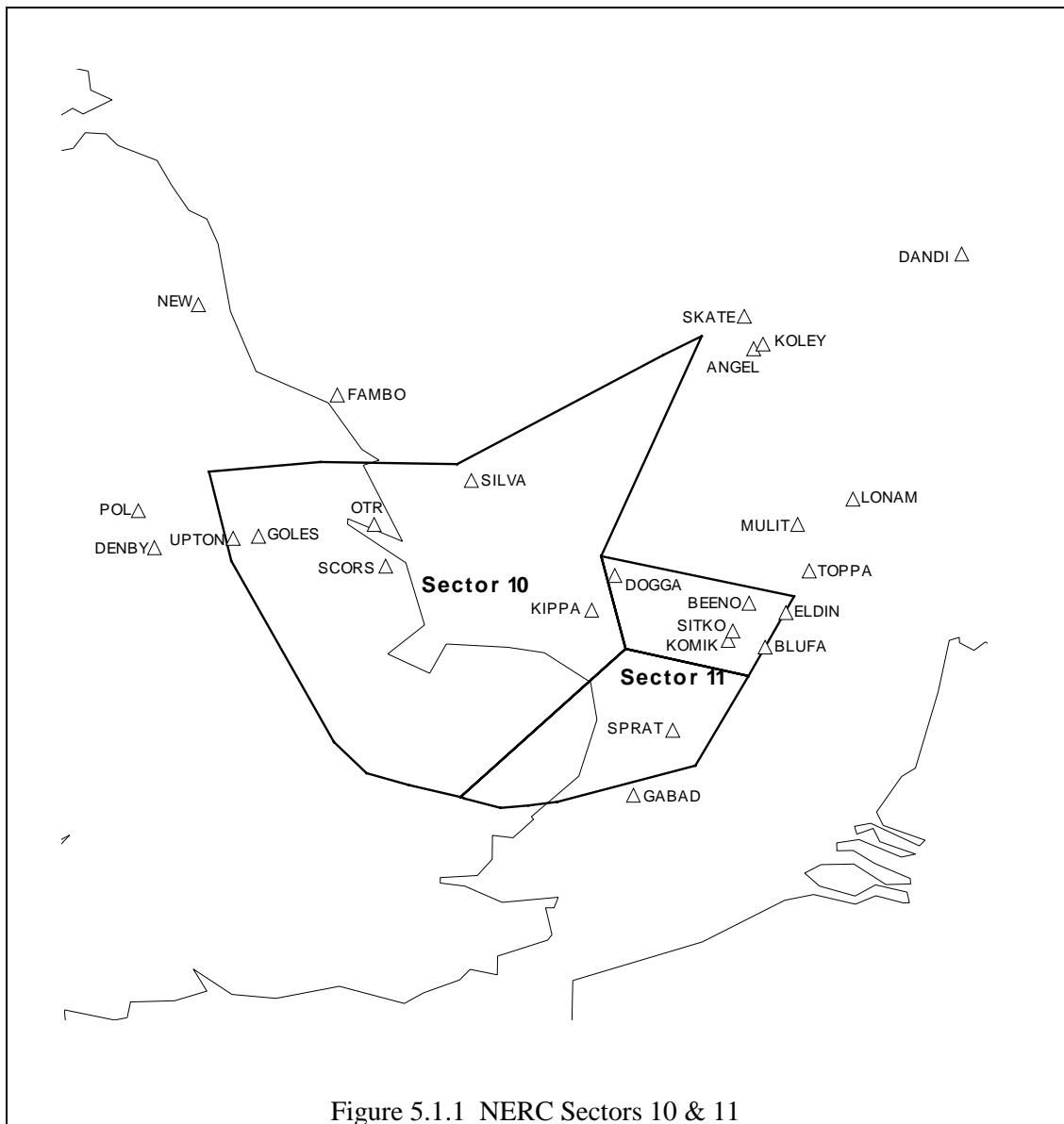
5. SIMULATED ENVIRONMENT

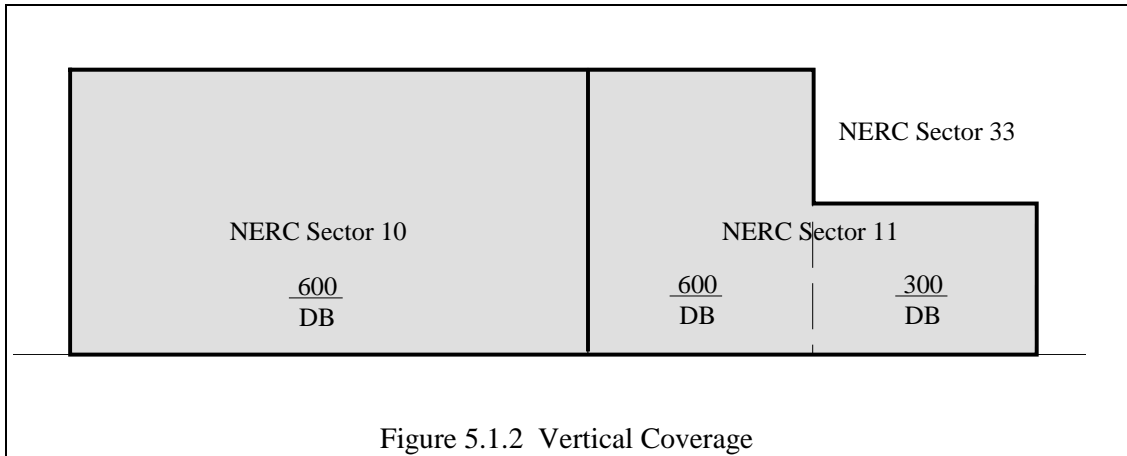
5.1. SIMULATED AIRSPACE

PD1 trials will be based on the airspace defined by the CAA's NERC sectors 10 and 11. The sectors will be modified to correspond with the sectorisation expected to exist in the year 2000. TMA and en-route sectors feeding these en-route sectors will be emulated.

Figure 5.1.1 shows the geographical coverage of the sectors. Figure 5.1.2 shows the vertical split of the coverage.

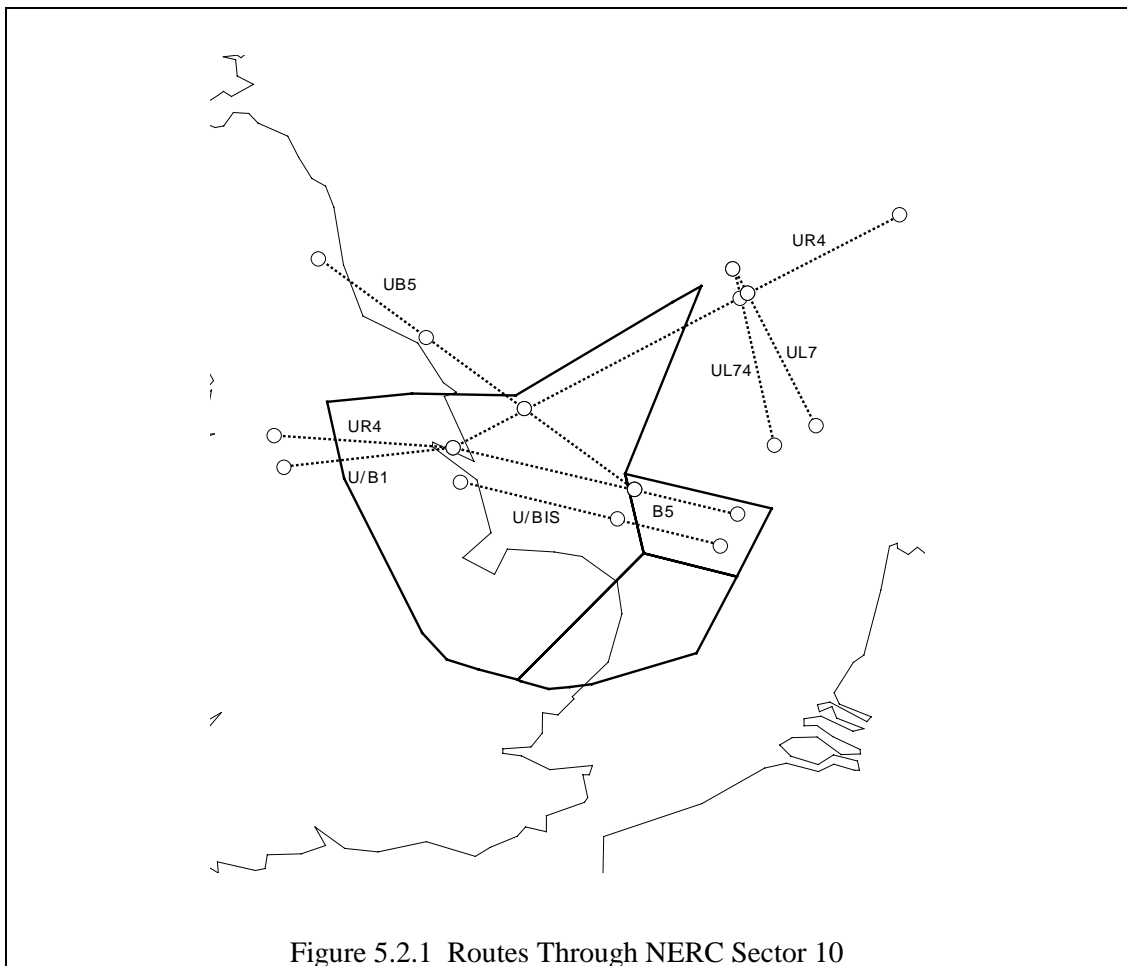
Full details of the airspace structure, including the lat./long. coordinates, can be found in the PD1 Facility Specification, reference 3.





5.2. ROUTE STRUCTURE

The routes through the sectors are shown in Figure 5.2.1 and Figure 5.2.2. Full details of the route structures in NERC sectors 10 and 11 are contained in the PD1 Facility Specification, reference 3.



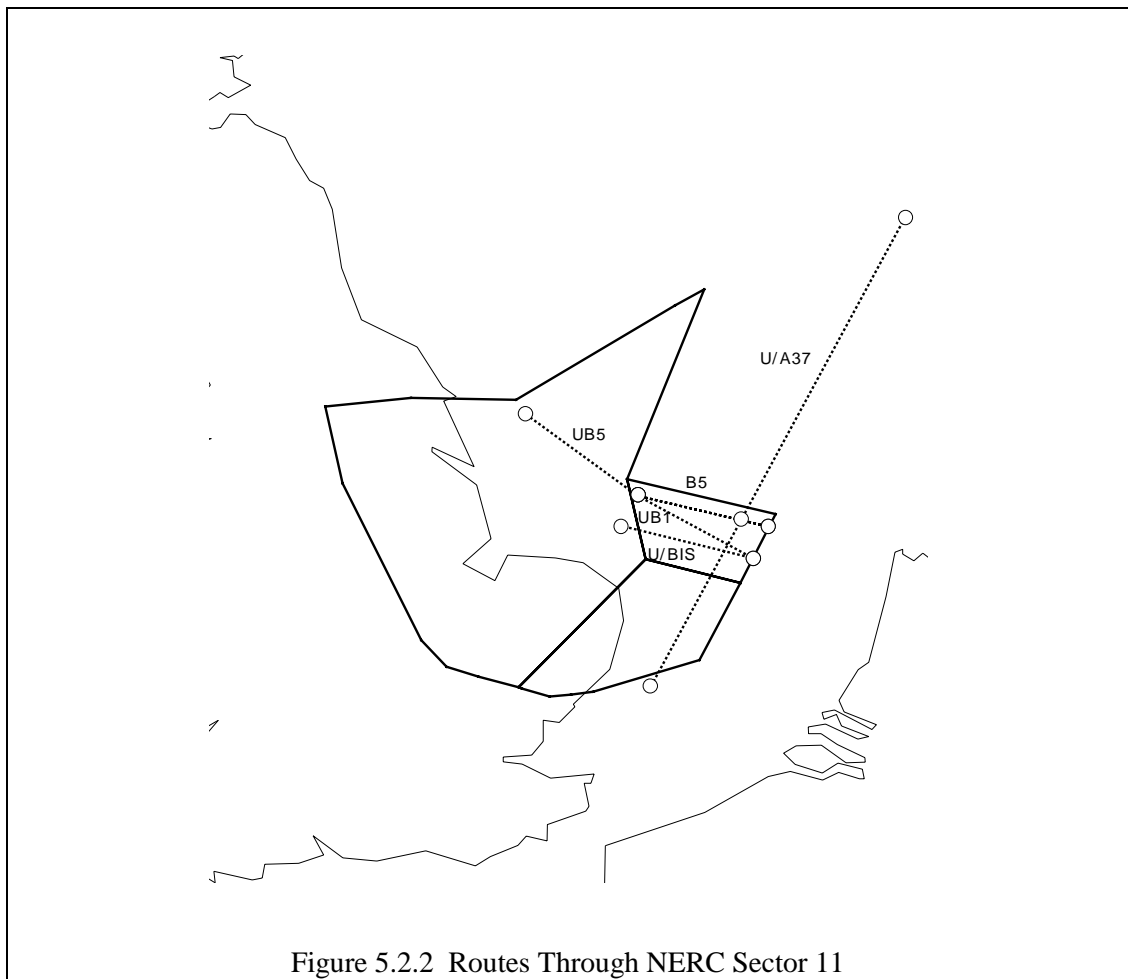


Figure 5.2.2 Routes Through NERC Sector 11

5.3. TRAFFIC SAMPLES

The traffic samples will comprise three flow rates centred around the expected traffic density in the year 2000. The samples will be representative of low, medium and high flow rates for this time frame and will use the latest forecasts for the year. Each sample will have a representative range of aircraft types and weights although the range will not be an experimental variable. The absolute values of these samples will be determined during the Facility Test and refined during the Pilot Phase of the demonstration to ensure an adequate distribution of traffic.

The traffic samples to support the three organisations will be characterised by the aircraft fit. All aircraft will be datalink equipped. For Organisation's 0 and 1 the datalink will support downlinked data, in Organisation 1 this data will be used to improve the accuracy of the ground based trajectory prediction. In Organisation 2 a percentage of 4D FMS equipped aircraft will be introduced. In conjunction with full-duplex data link these aircraft will support the exchange of downlinked trajectory data and uplinked ATC clearances. This Organisation will be supplemented by the inclusion of a live aircraft, the DRA (Bedford) BAC 1-11.

Each sample will be designed to present a workload throughout the measurement session which represents the appropriate flow rate with pseudo random short term variations introduced to simulate reality. The samples will be of greater duration than the measurement period so that a handover/briefing or warm up period can occur at the start of each

measurement and so that the end of the measurement period is not signalled to the subject by the sample behaviour.

Danger areas will be simulated where appropriate but no emergency procedures e.g. high jacking or diversion to airfields below the en route airspace will be simulated.

5.4. CONTROLLER GHMI

The Controller GHMIs will be an amalgamation of the HMIs used for ODID III, Organisation 2 and ODID IV. There will be two versions of the GHMI developed, one for the Reference System (ORG 0) and one for the Advanced Systems (ORGs 1 & 2). The use of only two interfaces to support the three ORGs will reduce the amount of time the controllers have to spend learning to use them. The Advanced GHMI shall be used for both ORGs 1 and 2 but different procedures will be used in the two ORGs. These different procedures will mean that certain features of the Advanced GHMI will not be used for ORG 1.

The Tactical and Planning Controllers shall have the same interface components available to them. However, the different uses of these components by the two roles shall be resolved as the procedures are clarified during the Pilot Phase. The controllers shall have limited flexibility in the setting up of the GHMI environment and it shall be possible to save the preferences of the controllers as part of the system.

The details of the GHMI are being developed in conjunction with the development of the controller procedures to ensure that the implemented GHMI will be able to support the procedures that are developed. The Facility Specification, Reference 3, contains information on the GHMI components.

5.4.1. Reference System

The Reference GHMI will operate in a stripless, both paper and electronic, environment and will primarily comprise a radar traffic display, with supplementary windows which will present the controller with the information which will normally be found on the bank of strips. All input to the system will be by use of the mouse. An example of the Reference System Ground HMI will be provided in the PD1 Facility Specification, reference 3.

5.4.2. Advanced System

The Advanced GHMI shall have the same components as the Reference System but will have added features which will enable the use of the PATs which will have been incorporated into the system. The interface will also have features which will enable the use by the controllers of the datalink facility. An example of the Reference System Ground HMI will be provided in the PD1 Facility Specification, reference 3.

6. GENERAL OPERATIONAL CONCEPT

6.1. PLANNING FUNCTIONS

When defining the division of tasks between the Tactical and Planning Controllers the aim is to attempt to smooth the peaks in the TCs activity and therefore enable him to control more aircraft. This will be achieved by the PC attempting to resolve potential conflicts before the TC is in control of the aircraft and leaving the TC to resolve only those conflicts which the PC cannot.

The split of responsibilities will be dependent upon the time frame within which the two controllers work, the PC will work up to 20 minutes in advance and the TC up to 10 minutes. This extended time is only possible if the controllers can be assisted in assessing the potential positions of the aircraft at a future point in time and can be helped to determine when a pair of aircraft are potentially in conflict. Under the current system the controller mentally extrapolates the positions of aircraft and notes which pairs of aircraft need extra consideration. These aircraft are then checked when the potential conflict becomes closer.

6.2. PROCEDURES

6.2.1. Planning Controller

6.2.1.1. Organisation 0

The procedures used for ORG 0 will be based on those used in NERC. This is a task sharing environment with a Planner and Tactical responsible for each sector.

The role of the Planner will be one of coordination. Coordination is achieved once the ACT message transmitted from the offering sector has been accepted and acknowledged by the receiving sector.

The PC will receive details of an incoming flight. After consideration of the level, routing and displayed radar data the PC may accept the traffic. The PC will determine whether or not potential conflicts exist by comparing the Entry Flight Level (NFL) or Cleared Flight Level (CFL) of traffic already accepted or the NFL with the Exit Flight Level (XFL) of traffic already accepted.

If a potential conflict is detected and the aircraft concerned are assessed on radar by the Planner as being capable of achieving and maintaining the specified planning separation the PC should accept the traffic. When assessing crossing separation the PC must base judgement on current intended flight plan route if different.

If a potential conflict is detected and the aircraft concerned are assessed by the PC as likely to have less than the required planning separation, the PC will either:

- a. ascertain whether the TC is prepared to accept the traffic, or
- b. telephone the previous sector and agree a revised coordination. In the case of traffic offering from a NERC sector the offering sector will amend the XFL otherwise the receiving sector will amend the NFL.

If the TC workload allows, the PC may seek the agreement of the TC to accept the aircraft into the sector on the understanding that the TC will ensure that appropriate radar separation

is maintained. If necessary, speed, heading or routing restrictions may be imposed. The PC will pass any such restrictions to the previous sector by phone.

Aircraft entering the sector under the terms of a standing agreement or offered from the same NERC sector do not require to be considered for potential conflicts at the entry point by the PC unless in conflict with another aircraft whose Flight Level is subject to allocation. It is the responsibility of the offering TC to ensure such aircraft remain separated.

The PC will have procedures for amending a coordination, the procedures will depend upon the source of the traffic, as follows:-

1. Traffic offering from an adjacent centre:
 - a. Agree amendment to co-ordination by telephone
 - b. Edit the NFL
2. Traffic offering from another NERC sector before acceptance:
 - a. Agree amendment to co-ordination by telephone
 - b. Accept traffic once it has been reoffered.
3. Traffic offering from another NERC sector after acceptance:
 - a. Agree amendment to co-ordination by telephone
 - b. Accept traffic following reoffer

When an aircraft is outbound from Sector the PC shall observe the following procedures. An XFL shall be allocated to an aircraft which will be transferred to an adjacent sector or an adjacent Air Traffic Control Centre (ATCC), except when aircraft are the subject of a standing agreement.

XFLs will be allocated in accordance with the notified convention for east and westbound levels unless alternative specified flight level allocation procedures are in use, or the receiving sector has agreed to accept an individual or series of aircraft using (On Line Data Interchange) OLDIs.

Aircraft may be offered to the next NERC sector at the same level provided that such aircraft will maintain a longitudinal separation of 15 nms or more. Aircraft which are not vertically separated may be offered to adjacent NERC sectors with less than the minimum planning separation with the agreement of the offering TC. Speed, heading or routing restrictions may be applied.

The PC must ensure that the allocated XFL is input to the system prior to the ACT time.

If no amendment is input the XFL will default to:

- a. standing agreement level where one exists, or
- b. NFL (for current simulation purposes).

If the receiving sector rejects a co-ordination, or if the offering sector requires an amendment to a co-ordination after ACT transmission; the re-negotiation must take place on the telephone.

In the case of traffic offering to a non-NERC sector, following agreement the XFL should be amended. In the case of traffic offering to another NERC sector, following agreement the PC will be able to reoffer the traffic.

6.2.1.1.1. Summary of PC Task

Use flight information, in association with radar data to identify and assess potential conflicts between aircraft offered into the sector under inter-sector coordination procedures or Transfer of Control agreement from adjacent ACC's.

Notify subsequent sectors, and TC of XFL.

Notify TC of:

- a. acceptance of co-ordinated traffic into the sector
- b. any traffic accepted into the sector which requires radar monitoring or intervention
- c. any special conditions applying to the transfer of aircraft to or from the sector
- d. agreed co-ordination or cleared flight path on military crossing traffic.

6.2.1.2. Organisation 1

Organisation 1 will use the PD1 Advanced System and will incorporate computer assistance tools from PATs. The GHMI will be enhanced to enable the controllers to interact with the tools and receive the information that the tools make available to them. Downlinked data will be available from the aircraft to improve the accuracy of the ground based trajectory prediction.

The Planner will agree Entry Conditions and plan Exit Conditions for conflict free trajectories through his sector using the Computer Assistance tools. He will attempt to plan conflict free routes through the sector which the TC may either accept or alter. Full details of the PCs role in ORG 1 will be contained in the PD1 Operational Scenarios document, reference 2.

6.2.1.3. Organisation 2

Organisation 2 will have full duplex datalink and a proportion of 4D FMS aircraft in the traffic sample. The use of the datalink will provide the controllers with more accurate information about the aircraft and the 4D FMS will enable aircraft to fly trajectories more accurately.

The Planner will carry out the same planning activity as in ORG 1 using the computer assistance tools, however the inclusion of 4D FMS equipped aircraft and the use of datalink to permit the exchange of trajectories and ATC clearances should increase the accuracy of the predictions. The Planner will have the facilities to enable communication with the aircraft via datalink should the operational procedures permit this. The procedures for the PC, including the use of the datalink, will be detailed in reference 2.

6.2.2. Tactical Controller

6.2.2.1. Organisation 0

The procedures used for ORG 0 will be based on those used in NERC. This is a task sharing environment with a Planner and Tactical responsible for each sector.

The Tactical Controller will be responsible for ensuring conflict-free passage of aircraft through his airspace. He shall perform all direct communication with the aircraft in his sector and will be responsible for all transfers. Transfer of Control is coincident with the sector boundary (or other defined position) unless the aircraft is operating under a Standing Agreement. In this case, Transfer of Control is coincident with Transfer of Communication provided that the receiving controller does not descend an outbound or climb an inbound and keeps the aircraft on any assigned heading or speed, until within the confines of the receiving sector.

The offering TC shall be responsible for ensuring that coordination takes place before an aircraft reaches the adjacent sectors airspace.

With lateral transfers the transferring TC must ensure before transferring communication that:

- a. The aircraft is either at or will make the Exit Flight Level (XFL) displayed on the label before the sector boundary.
- b. The aircraft is not in potential conflict with traffic within or entering the offering sectors airspace, whether in communication with that sector or not, unless notified to the receiving sector before transfer.
- c. The planning separation of 15 nms exists for aircraft on same route, without vertical separation.
- d. Any conditions agreed between the respective PCs have been met.

If any of the above conditions cannot be met the aircraft involved must be the subject of a radar handover, or new coordination effected.

With vertical transfers the transferring TC must ensure before transferring communication that:

- a. When climbing or descending an aircraft to be transferred vertically, the offering TC must ensure that the aircraft will be at the XFL by at least 15 miles before a laterally adjacent sector boundary. If this cannot be achieved it is the offering TC responsibility to ensure that any necessary coordination with an adjacent sector takes place.
- b. If an aircraft is transferred climbing/descending, to be level at the XFL at least 15 miles before the laterally adjacent sector boundary, and the receiving sector is unable to continue the climb/descent into it's airspace, it is the receiving TCs responsibility to coordinate with the laterally adjacent sector.

When transferring to adjacent ACCs Transfer of Control will normally take place at a point specified for each ACC.

It is the responsibility of the Tactical Controller to ensure that before an aircraft passes the receiving ATCC sector boundary that:

- a. The aircraft is conforming with the XFL displayed in the track data block.
- b. The separation criteria laid down in the Transfer of Control agreement with that ACC have been achieved.

If the above conditions cannot be met, the aircraft involved must be the subject of a radar handover, or new co-ordination effected.

Transfer of Control without radar handover (Silent Handover) may be effected between adjacent NERC sectors and between NERC sectors and other units where a standing agreement exists, or between adjacent NERC sectors and specified ACC's, subject to the following:

- a. The aircraft must be displaying a discrete SSR identity and,
- b. The aircraft must be within the anticipated displayed radar cover of the receiving sector.

Before giving an executive instruction to an aircraft which has been transferred by Silent Handover, the receiving controller is to identify it and allow the pilot to make his initial level report.

Additionally, where Silent Handovers are in force between adjacent ACC's the following conditions apply:

- a. Labelled SSR displays (including Mode C) must be serviceable at both units.
- b. Direct radar to radar telephone lines between both units must be serviceable.

When an aircraft is to be transferred from one sector to another with a heading or speed restriction, the information is to be passed to the receiving sector of ACC by one of the following methods:

- a. by telephone before communication is transferred or,
- b. by instructing the pilot to report the restrictions on his first call to the receiving sector.

N.B. NERC sector to NERC sector The receiving sector TC cannot release an aircraft from it's radar heading until it is within the confines of his sector.

Where Silent Handovers are not in force, Transfer of Control by Radar Handover may be effected provided that radio communication with the aircraft is retained by the transferring controller until the accepting controller agrees to assume responsibility.

6.2.2.1.1. Summary of TC Task

The TC's tasks can be summarised as follows:-

1. Check current situation
2. Select next aircraft for attention
3. Check related flight plan information
4. Check PC generated information
5. Check for conflicts
6. Determine next control actions
7. Agree exit conditions with next sector if necessary
8. Communicate with aircraft
9. Monitor for ACK conformance

6.2.2.2. Organisation 1

Organisation 1 will use the PD1 Advanced System and will incorporate computer assistance tools from PATs. The GHMI will be enhanced to enable the controllers to interact with the tools and receive the information that the tools make available to them. Downlinked data will be available from the aircraft to improve the accuracy of the ground based trajectory prediction.

In ORG 1 the TC will still maintain the same responsibility for ensuring conflict free passage and handover. The TC will still carry out all communication with the aircraft. The computer assistance tools will be available to the TC, however the use of these would be very limited in the timescale in which the TC operates. The TC's procedures, including the use of computer assistance tools, will be detailed in reference 2.

6.2.2.3. Organisation 2

Organisation 2 will have full duplex datalink and a proportion of 4D FMS aircraft in the traffic sample. The use of the datalink will provide the controllers with more accurate information about the aircraft and the 4D FMS will enable aircraft to fly trajectories more accurately.

In ORG 2 the TC will again maintain the responsibility for ensuring conflict free passage and handover. The Tactical Controller will be able communicate with the aircraft via the datalink, the aircraft will send down a suggested trajectory and the TC will respond by either accepting the trajectory, proposing alternative trajectories or constraints on the suggested trajectory. Full details of the TCs procedures in ORG 2 will be contained in reference 2.

6.3. COMMUNICATION

6.3.1. Ground/Ground Communication

Coordination with adjacent sectors will take place mainly via computer/computer interaction instigated by controller action. Voice communication will be provided, via simulated telephone and intercom facilities, to handle complex or non-routine tasks.

A full description of the facilities to be provided to support PD1 is given in the PD1 Facility Specification, reference 3.

6.3.2. Air/Ground Communication

The PD1 scenario assumes all aircraft are datalink equipped. For ORG 0 the datalink will not be used. For ORG 1 the datalink will provide downlinked information to supplement the ground data. ATC communication with the aircraft will be via R/T.

For ORG 2 a number of 4D FMS equipped aircraft will be introduced into the scenario together with full duplex datalink capability. These aircraft will have the capability to exchange trajectory data with the ground and receive ATC clearances via the datalink. The use of the datalink or voice communications for ATC instructions will be defined in the Operational Scenarios document, reference 2. However it should be noted that voice communication will always be available to all aircraft irrespective of datalink fit/capability.

A full description of the facilities to be provided to support PD1 is given in the PD1 Facility Specification, reference 3.

6.4. FEED SECTORS

The airspace to be simulated in PD1 comprises NERC sectors 10 and 11 together with adjacent TMA and En-Route feed sectors. In the simulation the feed sectors will be 'manned' and will be equipped with facilities necessary to perform the co-ordination role and hence provide a realistic environment in which the measured sectors can operate.

It is not necessary that feed sector 'Controllers' are experienced ATC staff. They should be trained in the coordination procedures and to a level of competence, commensurate with the pseudo pilots, in the use of R/T.

7. SIMULATION PLAN

7.1. GENERAL

The simulation programme is planned in two phases, a pilot and a main phase. In the pilot phase an exploratory type investigation with freedom for adaptation by the controllers will be performed. The main phase will be more rigorously organised to allow statistically valid experiments to be performed.

7.2. OUTLINE TIMETABLE FOR REAL-TIME SIMULATION

In order to carry out the simulation it is intended to build two different systems to support the controller, the Reference System and the Advanced System.

The completion of the initial Reference System will be followed by a period of trials identified as the Reference System Calibration in the PD1 Project Plan. The aim of this period of tests is to allow controllers who know the environment simulated to exercise the system and compare it with the workload from their real system experience. The system will then be assessed by non-locals to eliminate the effect of experience and bias.

Following this calibration exercise the system will undergo further development to incorporate the PATs and datalink aspects of the system. The assessment and validation system will also be adapted in order to meet the requirements of the experimental methodology to be used.

Once the systems have been integrated there will be a final Facility Test which will include aircraft and the full complement of controllers needed to run the facility. This will be the last rehearsal before the Pilot Phase.

Before the Pilot Phase it will be necessary to organise the evaluation in detail and train the operators. This will include all logistic work necessary to organise availability of people and equipment at the correct time, the training of operators with all systems involved in the exercise, the briefing of ATC controllers and (pseudo)pilots. The Pilot Phase will be used to fine tune the experimental facility to reduce the number of options and combination of variables to be used in the Main Phase, to make last minute adjustments to the operational procedures associated with each organisation and then to carry out *ab initio* training of the controllers who will take part in the Main Phase of the demonstration. In order that statistically valid results can be derived it is essential that the subjects are provided in groups which are maintained throughout the Pilot Phase and the Main Phase trials. Subjects will be trained into either the Planner role or the Tactical role and will retain that role throughout.

The main phase is scheduled for late-1995. This Main Phase will involve the performance of a structured evaluation exercise according to a predefined experimental programme. Eight weeks of trials are scheduled. Each week will include the re-training, briefing and subsequent debriefing of controllers, (pseudo)pilots and system operators, the performance of the sessions and the gathering and consolidation of results from the various recording facilities. An exercise log will be kept during the period of the trial. Figure 7.2.1 summarises the Proposed Timetable of Events.

The DRA (Bedford) BAC1-11 will be used for some of the trials to demonstrate the operation of the system with a "live" aircraft. These trials will incorporate the weather actually encountered by the aircraft.

Phase	Duration
Calibration	16 weeks
Facility Test	8 weeks
Organise evaluation and train operators	8 weeks
Pilot Phase	4 weeks
Main Phase	8 weeks

Figure 7.2.1 Proposed Timetable of Events

7.3. REFERENCE SYSTEM CALIBRATION PHASE

The objectives of the Reference System Calibration Phase are as follows:-

1. To test the Reference System software and hardware for functional performance and to correct any problems.
2. To test the Reference System for operational performance and in discussion with controllers adjust workload to a level which reproduces the current system operational workloads.
3. To try out operational procedures and modify them to controller satisfaction.

The Reference System Calibration Phase covers a period of 16 weeks from February to June 1994. The outline of the plan for this period is of necessity less precise than the programmes for the later phases.

Weeks 1 to 8	Internal development and testing of software and of functional behaviour. Use of non-operational controller advisors on one day basis. No formal trials but use of reasonable low rate traffic samples.
Week 9 to 11	One or two day testing of software, HMI and Operational procedures. Single sector testing. Use of realistic samples. Use of non-operational controllers to check system. One or two day visits, modifications made between runs where possible.
Week 12 to 13	First formal system test week. Operational controllers on site for properly run 1 hour trials. Two sector trials. Debriefing to tune system and procedures. Comparison to workload of real system. Adjustment of trial sample traffic samples to achieve realistic loading.
Week 14	Change implementation week. New sample creation, HMI modification and new procedure development as necessary to take account of controller comments.
Week 15	Final testing week for Reference System. Operational controllers available all week. Tests of adjustments made, modified procedures and of trial traffic samples to determine levels for Pilot runs to achieve formal training.
Week 16	Final changes to system and procedures.

7.4. FACILITY TEST PHASE

The Facility Test Phase will occupy eight weeks. The objectives of the Facility Test Phase are as follows:-

1. To carry out initial tests of the Advanced System for functional performance and to correct any problems
2. To carry out initial tests of the Advanced System for operational performance and adjust to take account of controller suggestions.
3. To carry out initial tests of the operational procedures and modify them to take account of controller comment.

Parts of this period will be structured in a similar fashion to the Reference System Calibration phase during which system and procedures shakedown will take place. During this period test runs will be carried out with non-operational but qualified controllers performing short single sector runs and commenting as they progress. Changes will be implemented, tested and documented between runs.

There will also be a shake-down period, during this time test runs will be carried out with qualified, non-operational controllers performing full length measured trials. The principle aim is to adjust the parameters of the tool set and to test and adjust the scenarios for their work loading on the controllers.

7.5. PILOT PHASE

The Pilot Phase will comprise 12 weeks. The objectives of the Pilot Phase are as follows:-

1. To further test the Advanced System for functional performance and to correct any problems
2. To further test the Advanced System for operational performance and adjust to take account of controller suggestions.
3. To further test the Operational Procedures and modify to take account of controller comment.
4. To tune and modify the tool parameters.
5. To establish scenario loading for low, medium and high traffic samples.
6. To train subject controllers on Reference and Advanced System and associated procedures in preparation for the Main Phase.
7. To train the Pseudo Pilots for Main Phase.

The first 4 weeks will be devoted to tuning the tools and scenarios to achieve realistic trials in the Main Phase. The last period of the Pilot Phase will be the training of the subject pairs to the use of Reference and Advanced Systems in preparation for the Main Phase measured trials. This will be much more tightly planned in order to optimise the controller attendance demand and make the most of the time during which they are available.

Changes will be implemented, tested and documented between runs. The measurements taken during these runs will not form part of the final analysis but are for adjustment of the stated experimental parameters.

From previous trial experience it has been assessed that it will take at least three days to train each pair of controllers into the two systems, Reference and Advanced, including the procedures which effect the essential difference between Organisations 0, 1 and 2.

7.6. MAIN PHASE

The objectives of the Main Phase are as follows:-

1. To study the effect on controller workload and traffic throughput of the introduction to and use by en-route controllers of PATs tools.
2. To study the effect on controller workload and traffic throughput of the increasing proportion of 4D FMS aircraft with their capability for 2-way datalink.
3. To encourage and obtain Controller acceptance of the tools and their operational use.

In order to obtain meaningful results from the trials the Objectives 1 and 2 above must be studied by separate trial series for each case in which individual comparison with the Reference System is made for a single varying parameter.

The following series of trials is proposed:

Trial No	System	Aircraft Mix	Flow Rate
1	Reference	Mix 1	Flow 1
2	Reference	Mix 1	Flow 2
3	Reference	Mix 1	Flow 3
4	PATs	Mix 1	Flow 1
5	PATs	Mix 1	Flow 2
6	PATs	Mix 1	Flow 3
7	PATs	Mix 2	Flow 1
8	PATs	Mix 2	Flow 2
9	PATs	Mix 2	Flow 3
10	PATs	Mix 3	Flow 1
11	PATs	Mix 3	Flow 2
12	PATs	Mix 3	Flow 3

In which

Mix 1	0% 4D FMS aircraft
Mix 2	30% 4D FMS aircraft
Mix 3	70% 4D FMS aircraft
Flow 1	2000 low
Flow 2	2000 medium
Flow 3	2000 high

Objective 1 is achieved by the use of measurements from sessions 1 to 3 with 4 to 6.

Objective 2 is achieved by the use of measurements from sessions 4 to 12.

Objective 3 above will be achieved by the analysis of a range of subjective and objective tests applied to the subjects during each trial. This set of tests is to be agreed with the PHARE Validation and Tools group and will include questionnaires and workload assessment measurements.

Trials 1 to 3 of this series will be run as a set with ordering randomised and will establish the reference performance. Trials 4 to 12 will be run as a second sequence also randomly ordered and will provide the comparative data from which the effects indicated as Objectives 1 and 2 above will be measured. An extra trial at the end of the main series is proposed in which a repeat of one of the Reference system sessions will be carried out. This will enable a measure of the effect of continued learning of the use of the HMI by the controllers through the trial period to be assessed.

In order that statistically valid results can be derived, these trials should be run for a minimum of eight sets of subjects. A set of subjects is two for each of the two sectors being simulated, a total of four subjects required for each week. Subjects will be trained into either the planner role or the Tactical role and will retain that role throughout. It is preferable that the subjects are provided in pairings which are maintained throughout the Pilot Phase and the Main Phase trials. The Pilot Phase will be used to provide the *ab initio* training in preparation for the Main Phase trials.

8. TOOLS

This section identifies the basic functionality of the advanced computer assistance tools to be incorporated in PD1. A Reference System (ORG 0) will be built without, PATs, to establish a performance benchmark against which the "benefits" of the computer assistance tools can be measured. The PHARE Advanced Tools (PATs) programme is developing a range of computer assistance tools of which the following will be used in ORG 1 and ORG 2:-

Trajectory Predictor (TP)

This function will provide, according to a set of constraints, the resulting trajectory of the aircraft including uncertainty data around the 4D path.

The "look ahead" time for the prediction will be one of the variables for the simulation.

Kernel services:

- Initialise constraint list for an aircraft;
- Calculate 4D path for an aircraft;
- Generate Modelled Error Tube.

Composite services:

- Generate Alternative SPL (System Plan);
- Earliest/Latest arrival times at a 3D constraining point.

Active service:

- Maintain Active SPL.

Flight Path Monitor (FPM)

This function will dynamically compare aircraft positions (derived from surveillance data) against an SPL and raise an alert if the position is not within a pre-set threshold. The thresholds for the allowed deviations are to be specified.

Kernel service:

- Determine deviation between Active SPL and surveillance data.

Active services:

- Signal when Active SPL has become infeasible (Warn of deviations);
- Gather extra information.

Conflict Probe (CP)

To be used in conjunction with the TP and FPM to provide the controller with advance warning of potential conflicts. It will dynamically check the SPLs for conflicts with other aircraft, but will not check against areas or meteo hazards.

Kernel service:

- Check a pair of SPL's on conflicts.

Composite service:

- Provide conflict report on n Alternative SPL's.

Active services:

- Provide full conflict report on Active SPL's;
- Evaluate conflicts between SPL's and other constraints.

Negotiation Manager (NM)

This function will support the data exchange between air and ground as well as the communications between simulated sectors and controllers (Planning and Tactical) within the sector and hence will implement both the air/ground and ground/ground protocols. The NM will coordinate SPLs within and between sectors. All downlinked data will be routed via the NM. The NM will not negotiate SPLs with the aircraft, however it will send ATC clearances to the aircraft in ORG 2 but not ORG 1.

Kernel services:

- Implement air/ground negotiation protocol;
- Implement ground/ground negotiation protocol;
- Provide Standard Constraints.

Composite services:

- Co-ordinate SPL with a sector;
- Update SPL status.

Active service:

- Co-ordinate SPL through several sectors.

Problem Solver (PS)

Initially the Problem Solver will generate directives to the controller to assist in solving identified conflicts for an aircraft. The PS will not generate directives for controller to solve identified conflicts, will not resolve a conflict situation or indicate constraining areas or parameters. It is assumed that it will be used on controller request.

Kernel services:

- Generate an alternative conflict-free SPL for an aircraft;
- Verify new or modelled alternative SPL.

Composite services:

- Propose n alternative conflict-free SPLs.

9. MEASUREMENTS AND ANALYSIS

The aim of the PHARE Demonstrations is to show quantitative productivity increase which can be expected from introducing advanced computer assistance tools and data link facilities, as well as controller approval of the new working environment. However, the experiments are not expected to provide validated and exact reference values for future En-route capacity but they should be able to verify the feasibility of a highly integrated system under near reality conditions. Full details of the measurements and analysis to be performed are provided in the PD1 Facility Specification, reference 3.

A number of measurement techniques will be identified by the PHARE Validation Tools group which will be used to evaluate questions relating to performance, workload and acceptance. The aim is to apply, as far as possible, the same experimental procedures and techniques to the individual PD's.

Two categories of measurements have been identified, mandatory and optional. The mandatory measurements will be applied in all simulation runs of the Main Phase and will be for quantitative evaluation. The optional measurements are those for analysing and documenting individual simulation runs and are to be applied predominantly in the Pilot Phase experiments.

The measurements to be used for the evaluation of PD1 will refer to the following criteria:-

- performance (quantitative traffic handling), this will be manned system performance as well as operator performance;
- workload, in a highly automated system the will largely be a matter of mental load on the controller. In addition to peak workload, the questions of underload and situation awareness should also be addressed;
- acceptance (controller approval), this refers to the man/machine interface as well as the operational procedures.

The methods used to measure these criteria must be non-intrusive. Any techniques which require a controller to perform a secondary task are considered to be too intrusive for use in the Main Phase. Physiological measurements and eye movement recordings which might be perceived intrusive and also require considerable effort in subject preparation and calibration will be considered only as optional methods.

Mandatory measurements will concentrate on the following groups:-

- system output data, this will include "objective" metrics describing performance aspects, such as accuracy of flight path observance, traffic flow, and delay/economy figures in a given ATC scenario;
- operational data, this will include the registration of events depending on subject behaviour (such as communication behaviour) or operator inputs (frequency, errors etc.). The operational aspect may also include visual perception and decision making;
- controller judgements and opinions, these measurements will be collected by means of questionnaires, post-session interviews and debriefings.

10. ABBREVIATIONS

ACK	Acknowledgement
ACT	Activation
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATM	Air Traffic Management
CARD	Conflict And Risk Display
CFL	Cleared Flight Level
CMS	Common Modular Simulator
CP	Conflict Probe
DB	Defined Base
EATCHIP	European ATC Harmonisation and Integration Programme
FMS	Flight Management System
FPM	Flight Path Monitor
GHMI	Ground HMI
HMI	Human Machine Interface
NERC	New En-Route Centre
NFL	Entry Flight Level
OLDI	On Line Data Interchange
PATs	PHARE Advanced Tools
PD1	PHARE Demonstration 1
PHARE	Programme for Harmonised Air Traffic Research in EUROCONTROL
PC	Planning Controller
PS	Problem Solver
R/T	Radio telephony
SPL	System Plan
SSR	Secondary Surveillance Radar
TC	Tactical Controller
TP	Trajectory Predictor
TMA	Terminal Manoeuvring Area
VAL	Validation Tools
XFL	Exit Flight Level

REFERENCES

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2. PD1 Operational Scenarios, (PHARE/CAA/PD1-7.1/OSD;1), to be reviewed at PRT/3
3. R M Gingell, B Bradford and S A Fox, PD1 Facility Specification, (PHARE/CAA/PD1-2.2/FAC;1)

RELATED DOCUMENTS

Pre-Specifications for a PD/1 Simulation, PHARE/CENA/PD1-1.2/OPS;0 (Draft)

PHARE Demonstration 1, Working Paper 8, Operational Requirement for the PD1 Tools, R M Gingell, PD1/31.4

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Configuration Control Document

This document will contain the status in terms of version of all the PD1 related documents and will be re-issued whenever a document is updated.