PROGRAMME FOR HARMONISED AIR TRAFFIC MANAGEMENT RESEARCH IN EUROCONTROL

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PD/3 IOCP Programme

Human Centred Approach

EXPERIMENT REPORT

PHARE/CENA/PD3-2.1.2/SSR;Version 1

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Foreword

During the PD/3 exploratory phase, a number of subjects were identified as potential study topics, either of a technical, or operational nature. On the basis of this list of topics, it was decided to include in PD/3 an initial phase of clarification projects aiming at:

- providing an incremental development process leading to large-scale demonstrations ;
- clarifying the PD/3 Operational Philosophy and the definition of the final demonstrations scenario ;
- validating partial options or concepts before integration into the large-scale demonstrations.
- each project was defined and costs estimated. Considering the limited resources and time available, this programme was tailored to an achievable number of clarification objectives, focusing on operational aspects, with one objective performed by each core PD/3 establishment. This led to initiating three Internal Operational Clarification Projects (IOCPs):
  - the “Multi-Sector Planning Procedures” IOCP at the EEC,
  - the “Human Centred Approach” IOCP at the CENA,
  - the “ETMA/En-Route Interface” IOCP at the NLR.

The programme of IOCPs was initially planned to take place during 1995 and 1996, but was later extended into 1997 to take into account its linkage with major platform developments for the final demonstration. 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 IOCP (entitled “PD/1 Follow-up”), expanding the research into the PD/1 results.

The full programme of IOCPs was successfully completed in April 1997, each of the studies being associated with the publication of separate PHARE Study Reports indicating the findings and recommendations in view of refining the Operational Scenarios of PD/3 as well as the final set-up of the Demonstrations.

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EXECUTIVE Summary

The aim of the Human Centred Approach Internal Operational Clarification Project (managed by the CENA) was to contribute directly towards the preparation of the final PD/3 demonstration by refining the use of the Co-operative Tools in the En-route control position. The IOCP experiment took place in April 1997 at CENA Toulouse. The airspace simulated was based on the two En Route upper sectors UN/XN and UR/UY from Reims, each sector being staffed by one planning controller and one tactical controller. There were four controllers for two weeks: two from Aix and two from Bordeaux.

Through this experiment, and in spite of some system malfunctions, several concepts have been put into practice and a lot of experience gained about the following concepts:

- the introduction of DataLink,
- the anticipated planning tools (Activity Predictor and Trajectory Editor with a quasi dynamic What if),
- the filtered views and extrapolation (i.e., continuous dynamic projection of the relative positions of aircraft on the Plan View Display),
-
- the concept of Area of Common Interest (displaying filtered views at the boundaries of the sectors), to alleviate co-ordination with the next receiving sectors.

The use of the Activity Predictor is seen as a promising support tool for team work and the extrapolation function was highly appreciated by the controllers.

The experiment also highlighted some of the consequences which the anticipated planning working method seemed to generate:

- the radar display was felt to be too small and not easily compatible with the anticipated planning aim which required a sufficient extended vision out of the sector ;
- this new working method led to many communications between controllers at the same working position and also between sectors, related to co-ordination before planning an a/c. It was observed that the anticipated planning method led the PC to work according to the a/c global trajectory rather than the crossed sector.

The tools which allowed controllers to anticipate, plan and edit a trajectory were not always felt as workable as they could have been, partly because of the controllers’ exposure to their use was not as long as would have been expected.

The underlying concepts of the Co-operative Tools were generally accepted, but the level of controllers' practice was not high enough at the end of the training week to show any measurable benefit on traffic fluidity.

The operational guidelines should have ensured better traffic integration than they did.

Many lessons were learnt during this IOCP and they need to be considered in PHARE Demonstration 3, especially concerning the choice of evaluation methods and the HMI design. For example, the tiredness of the controllers after the runs has to be taken into

account: asking them to provide a verbal report and to reply to a questionnaire, etc. seemed to be too demanding. An other issue concerns the TLX vocabulary which has to be adapted to the controllers' activity.

TABLE OF CONTENTS

1. Introduction

1.1 The Human Centred Approach

Following the review of the PD/3 Demonstration in early 1996, the Human Centred Approach concept was retained in the advanced scenario for PD/3. This concept aims at providing tools which fit the controllers' cognitive process and enables them to improve their effectiveness and retain their decision making ability as well as responsibility in an operational scenario. The major contribution to this approach is the PHARE Advanced set of tools called "Co-operative Tools", which are designed to address bottlenecks of the present controllers' activity (memorisation, information filtering, co-operation inside the team). The support provided by these tools should take these bottlenecks into account and try to make up for them. These bottlenecks are the problems to overcome, if we want to alleviate controllers' workload. This "problem driven" approach enabled the definition of the major functions of the Co-operative Tools (information Filtering and Activity Predictor, detailed in 3.2.4) and the design of associated working methods.

1.2 Context of the CENA IOCP

This experiment took place in the frame of the PD/3 IOCP programme. A series of real-time simulations was planned to evaluate the introduction of computer advanced tools and DataLink in En-route and extended terminal manoeuvre area (ETMA) through the improvement of traffic planning. Each PHARE Demonstration has been led by one of the PHARE partners.

This IOCP experiment focuses on the concepts related to the **working methods** and on **the integration of control aids** for the “en route ” (UAC space) control positions. More specifically, attention was paid on the evaluation issues listed in section 2. This was a development experiment focusing on **how to refine training and working method guidelines which have to be provided with the tools to enable an enhancement of the global system performance.**

About 40 % of the HMI specification for “ en route ” positions of the final demonstration are reflected in the available HMI, but, concepts related to MSP, to system supported inter-sector co-ordination and to ETMA/AAC and TMA positions were not addressed during these experiment.

As far as the "pseudo" trajectory negotiation is concerned, controllers have HMI functions at their disposal allowing to perform horizontal changes and send a route clearance resulting in a complete closed trajectory to the pseudo-pilot. This clearance is executed in due course by the flight.

Several concepts directly linked to PD/3 en-route control positions were missing in this experiment or were not exactly the same as they will be in PD/3 (notably HMI principles):

- no Multi Sector Planning,
- functions of the Activity Predictor partially developed,
- no trajectory negotiation with the a/c (only trajectory uplink),
- no system supported co-ordination between sectors,

- in general, no function linked to ETMA/AAC and TMA positions.

For example, we postponed the evaluation of the Air/Ground communication/ negotiation and of procedures of exchange of associated data (Do controllers detect “ at the right time ” the pilots’ request ? Have they got enough contextual information to analyse this request ? What about the eventual triggering of a time out linked to a no response, or a calling back on frequency if a problem arises, etc. ?).

1.3 Report structure

This report presents HCA IOCP objective, context, running and experiment results. Some results linked to different topics of the protocol are presented in a specific part to avoid redundancy and to facilitate the reading of this document.

Section 2 presents the aims and objectives of the experiment.

Section 3 describes the trial facilities, and contains a brief description of the available HMI functions, the traffic samples and the working method guidelines used during the trials.

Section 4 outlines the trial method, including the timescale, the controllers and the training. The measurements, the data collection and the analysis methodology are described.

Section 5 concentrates on the main results of experiment and gives details about evaluation issues.

Sections 6 and 7 give the conclusion and recommendations.

For each topic, we present results and the following information:

- general tendency concerning the topic: synthesis written when results contrast strongly;
- data regarding a specific experimental question;
- possible suggestions form the ergonomic experts (with a ERG SUGG coding in italics) or the controllers (with a CONTR SUGG coding in italic).

For each topic, we make a difference between results provided by the different types of data: observations, interviews (post-simulations and/or debriefing), questionnaire and quantitative data. We also reported the most relevant phrases of the controllers in italics.

Seven appendices are attached:

- Appendix A details trial results;
- Appendix B details the elaboration of traffic samples;
- Appendix C provides a synthetic table of each measured exercise that may have been affected by technical deficiencies;
- Appendix D describes the working method guidelines;
- Appendix E presents the detailed experiment time table;
- Appendix F contains quantitative data tables;
- Appendix G presents the ergonomics experts' and controllers' suggestion list.

2. Aims and objectives of the IOCP experiment

This IOCP aims at providing input to the sector control position specification with emphasis on the teamwork aspect, transfer and change of responsibility resulting from new working procedures and impact on the controllers' performance. It also aims at evaluating co-ordination between positions and within a position, influenced by the use of advanced tools (PATs) in an En-route environment.

The experiment follow up and data collection is described in section 4.5. They focused on six main themes that we sum up hereafter:

Performance, workload, user acceptance: Evaluate if Co-operatives Tools concepts and working methods participate to improve global system performance (fluidity, security, capacity). This theme was approached by qualitative data (controllers' opinion).

Anticipated planning: Is advanced and filtered information sufficient and efficient to plan an aircraft trajectory by anticipation and to choose a solution in the sector ? Do the controllers make any difference in planning equipped and non equipped aircraft ? Is the trajectory editor relevant and easy to use to plan and choose a solution ?

As the vertical trajectory editor was not integrated in this IOCP, this concept was not fully evaluated.

Co-operation between controllers of the same position: This theme deals with tasks sharing between PC and TC and tasks continuity. Does the TC get enough information on propositions made by the PC ? Is air traffic representation shared by both controllers ? What about communication between PC and TC ?

Some functions related to co-operation between controllers of the same position **were** not integrated in this IOCP (e.g. marking the flights that had already been planned by the planning controller) and their lack increases the communication load. The experiment showed that tasks related to this co-operation were very time demanding.

System updating: Workload related to system input , coding relevance ; utility and understanding.

Inter-positions co-operation[1]: Is APD (Activity Predictor Display) a good co-ordination medium between sectors ? How Co-operative Tools are used in case of an ACI problem ? Is anticipated planning (-10') adapted to the sectors ?

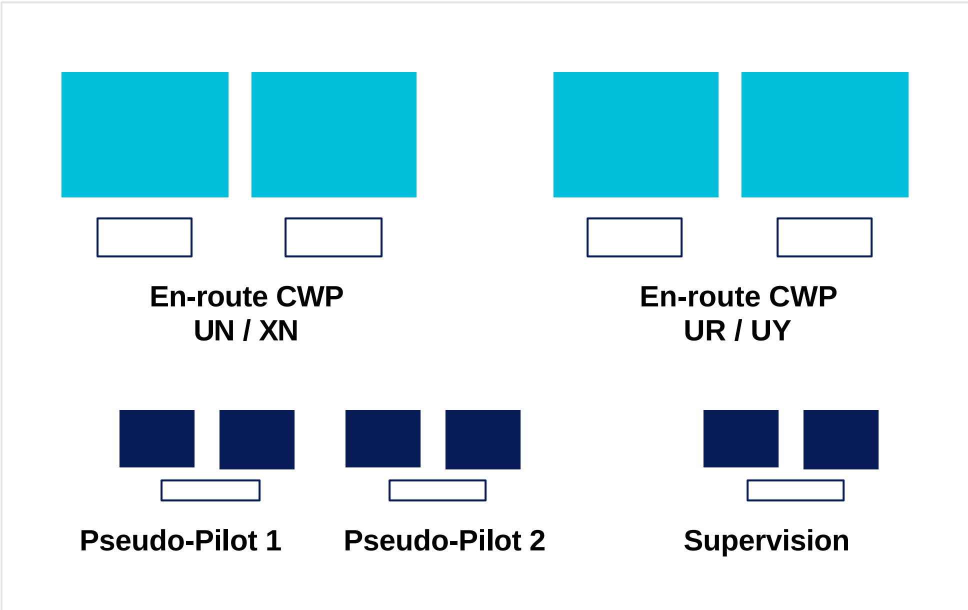
Operational quality of experimented tools and aids: Are offered functions easy to use, useful and adapted to the controllers' activity ?

[1] as mentioned in 5.2.2: " Co-operation between controllers of adjacent sectors", this issue could only be partially studied, du to the uncompletness of the platform.

3. Trial environment

3.1 Trial facilities

3.1.1 Simulation operational facilities



3.1.2 Simulated control positions

- Two simulated and measured control positions
- Equipment of a module (two modules for each position):
  - one 2000/2000 screen,
  - one mouse,
  - one telephone,
  - one headset (frequency simulation).

3.1.3 Pseudo pilot positions

- Two pseudo-pilot positions (1 pseudo pilot taking charge of both equipped and non equipped traffic for each simulated control position)
- Equipment of a position:
  - one double screen station for each pseudo pilot
  - one headset

- Human resources:
  - Profile of pseudo-pilots: characterised by a good knowledge of the piloting activity

- one pilot for each position

3.1.4 Adjacent passive pseudo position

Passive pseudo position: not manned position.

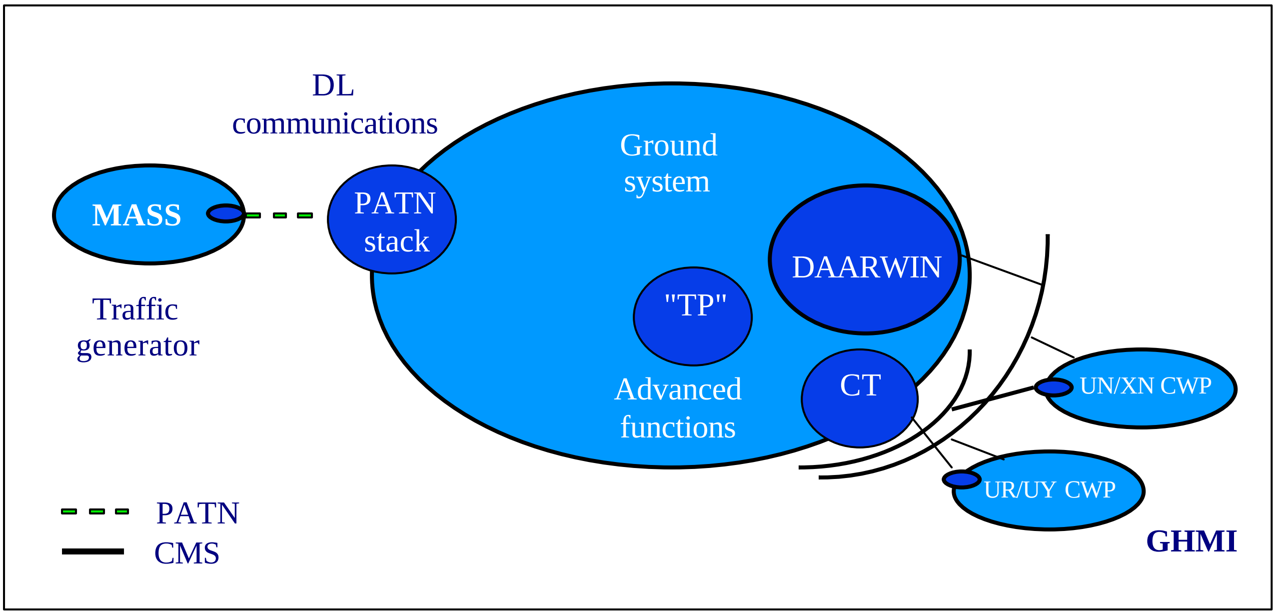
3.2 The available platform and its components

3.2.1 Overview

The experiment was supported by the standard CENA real time simulation platform (MASS + DAARWIN).

From a technical point of view, the "IOCP platform" is an intermediate version of the full PD/3 CENA simulator. **The CENA IOCP program is to be viewed as a step of the incremental development of the local PD/3 platform**. As figured in section 3.2.3, f

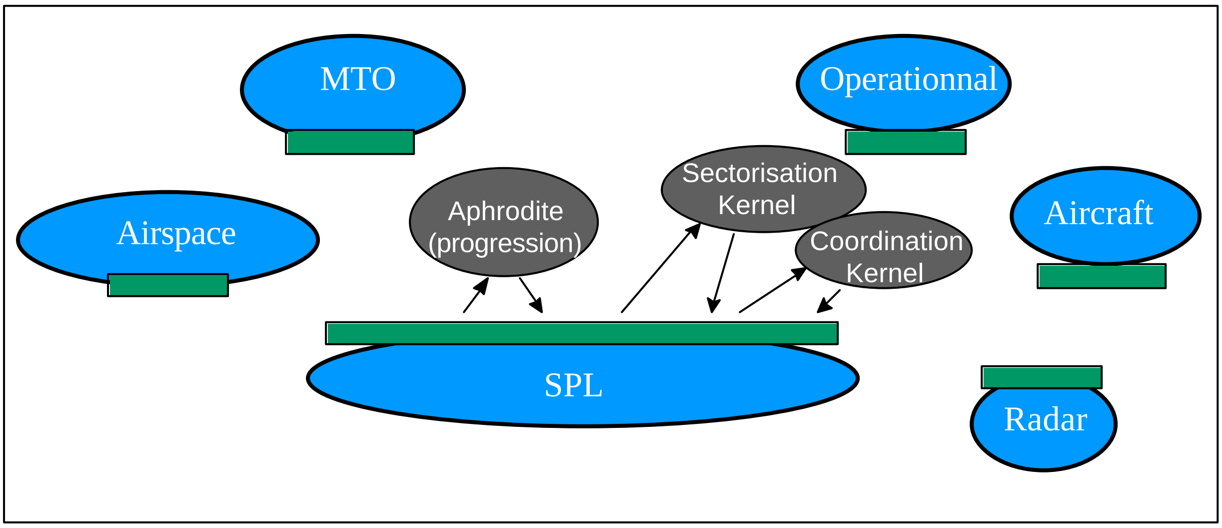
rom a functional point of view, the major available advanced functions were a CENA internal **trajectory predictor** and the **Co-operative Tools** ; the ATC simulator layer (DAARWIN) enabled to manage the concept of **advanced planning** and **the uplink of edited trajectories** was available through an adapted CPDLC function (and enhanced pseudo-pilot position and traffic guidance in MASS).



- **Ground system**: DAARWIN with CMS API for necessary services
- **Air system**: MASS
- **Advanced functions** : Trajectory Predictor + Co-operative Tools
- **GHMI**: dedicated CENA software development (above home toolkit)
- **DL communications** : PATN/CPDLC

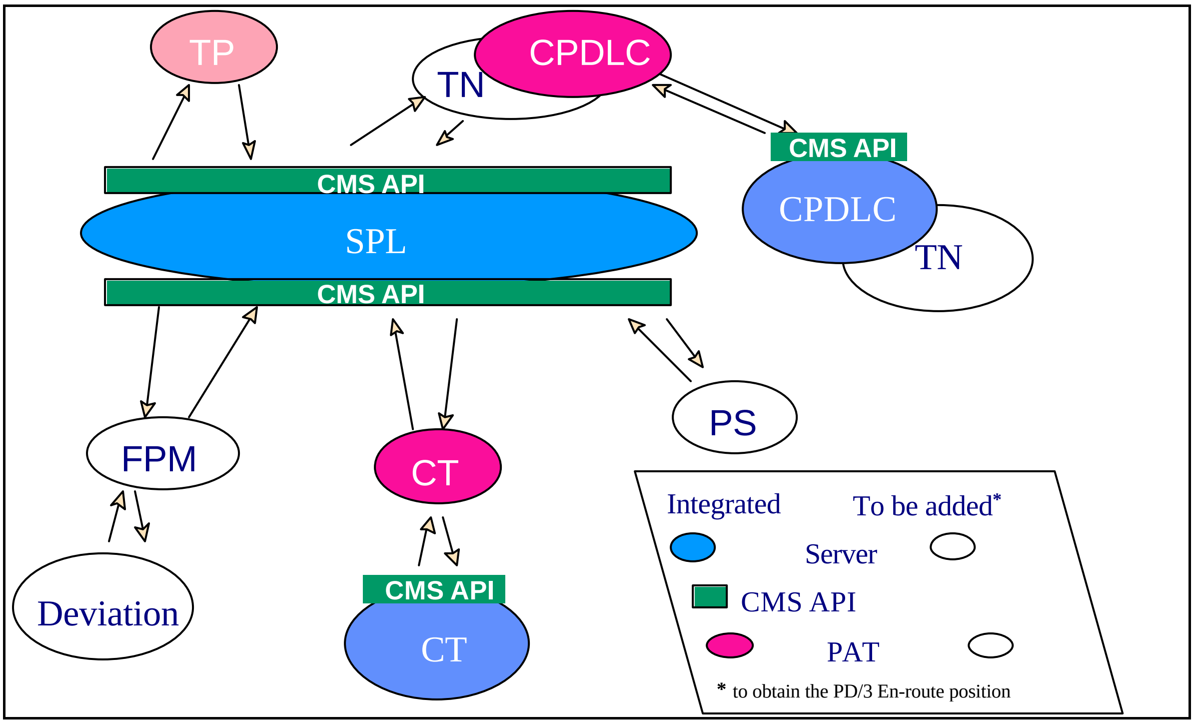
3.2.2 Ground system and CMS services

Below are figured the functions of the ground system that were used during the IOCP:



3.2.3 IOCP PATs integration

As far as the PATs' integration is concerned, CMS API were implemented and enabled to integrate Co-operative Tools, the CENA Trajectory Predictor, which is similar to PATs one and a CPDLC component (client + server). Although this last component will not be the major DL function in PD/3 (it will be used only for Frequency Change), its integration allowed to gain experience in interfacing PATN stack that will be used in PD/3.



3.2.4 Main functions in the IOCP

- **The problem and aircraft filtering function** (Co-operative Tool), which is based on "interaction detection": the object of the rules used in algorithms is to answer the question "given its planned trajectory, is this aircraft a matter of concern, considering this other aircraft, or a complex situation ?". If the aircraft is actually to be monitored carefully, or even to be moved, it will be part of the filtered image associated to one or several complex situation(s).

- **The activity predictor** (Co-operative Tool): this is a synthetic planning of detected complex situations: each one is given a date, according to its urgency: the controller then has to manage and use this list of complex situations to organise his/her work and choose his/her strategy according to traffic density and complexity that can be foreseen.
- **The area of common interest** (sectorization and co-ordination kernels): this concept was associated to the use of Co-operative Tools and anticipated planning to ease early handling of flights through providing information about aircraft further down their trajectories. Thanks to the filtering concept supported by the Co-operative Tools, this extra information is cut down to what is relevant: if an aircraft is involved in a complex situation in the next receiving sector, this is mentioned to the controller, who can take this into account if he/she has to change the aircraft trajectory.
- **The CPDLC "route clearance"**: this function was used to uplink horizontal trajectory changes to the aircraft. The objective was not to perform a complete negotiation with the aircraft, but to enable the controllers to plan and uplink horizontal changes of trajectories. Although this function is not meant to be used again during the PD/3 experiments, it was the only way for us to observe the impact of advanced planning on team-work and inter-sector co-ordination.

3.3 HMI facilities

Below are listed the main available HMI functions in the IOCP platform.

- Activity Predictor Display (APD):
  - APD window is used to provide special information related to air traffic. The window presents:
    - traffic problems for non equipped and equipped a/c (PROblem SITuations),
    - problems resolution in terms of new planned trajectories for non equipped a/c (PRORES),
    - traffic optimisation in nominal situations for non equipped a/c (PREPLAB). All this information is presented in label forms linked in a dynamic way to a time axis. Problem resolutions for the equipped a/c are not presented in the APD (there are no PRORES),
  - APD window enables to trigger a filtered view of a PROSIT (STU mode on the PVD), providing a traffic representation centred on the selected problem,
- APD window enables to trigger the extrapolation function focusing on a PROSIT, to provide a continuous dynamic projection of the positions of the aircraft involved in it.
- Trajectory Editor Flight Interaction (TEDI):

  TEDI provides an information display for the selected flight currently planned path through the sector, as well as an indication of interacting flights along the route. The use of TEDI allows to:

  - display the trajectory,
  - edit a new trajectory on RPVD,

  - validate the working trajectory,
  - plan an horizontal trajectory taking into account the Set of Interfering Aircraft via the SIA filtered view, for an equipped or non-equipped a/c, in a nominal or a problem situation (with a quasi interactive "planning aid", updating the interacting zones along the routes, each time a new trajectory segment is proposed).

- System updating:

  The controller updates the system through the use of menus (Callsign menu, Flight level menu, speed menu, climb/descent rate menu).

- The controller can configure the interface module by:
  - adjusting radar image,
  - personalising radar display,
  - using Labels windows,
  - using Label overlap Window.

- Receiving/displaying information on RPVD:

  The radar display presents:
  - the Sector Inbound List (SIL),
  - advanced information about an a/c,
  - the extended label of an entering a/c,
  - the trajectory,
  - an alarm clock to place on the trajectory to mark the anticipated planning of a flight level.

3.4 Working method guidelines

The guidelines provided to the ATCOs were structured around three major issues:

- task sharing on a given control unit,
- inter-sector co-ordinations,
- traffic mix handling.

The guidelines were first presented to the ATCOs during the introduction of the training session but not given formally at the very beginning. The guidelines were updated taking into account training feed back. They were given out to the ATCOs and considered as rules to be applied at the beginning of the second week.

Appendix D: Working methods guidelines presents these guidelines.

3.4.1 Types of clearances

Although this did not give way to an explicit statement in the written guidelines, the ATCOs were widely briefed on the necessity to issue "closed clearances" (open ended clearances were presented as resulting in a "degraded situation").

3.4.2 Task sharing

An emphasis was led on the management of **planning authority** and **control authority**: the PC is responsible for the flight 10 minutes before its arrival in his/her sector until the initial contact. The TC is responsible for the flight from initial contact till its transfer to the next sector.

"PC is responsible for the flight" means that he/she has to prepare and **make active** any necessary or desirable **strategic clearance**. A strategic clearance is a control order that is not applicable immediately, but later along the aircraft track[2], and ideally, within the sector for which the PC is responsible. Making a clearance active means that the result of the associated manoeuvre is considered as being the aircraft "probable future" and the system trajectory is updated accordingly.

The PC is asked to plan strategic clearances and input them as often as possible,

But, he/she should not issue a clearance if it seems better to wait: the PC is encouraged to leave a trajectory unchanged even when the flight is not conflict free, if the assessment of the situation (Activity predictor, filtering, extrapolation) shows that it will be more efficient to wait for the TC to issue a shorter term clearance.

The PC should explain his/her planning actions to the TC as often as necessary.

The TC should take the flight into account according to what was already done by the PC: already planned or action deferred.

The TC is the only one responsible for immediate (that is to say R/T) clearances (for DL and non DL flights).

3.4.3 Inter-sector co-ordinations

The PC should plan (change, decide to wait or to leave unchanged) a trajectory as early as possible.

If the PC can not plan the trajectory before the flight is "plannable" in the next receiving sector, the PC **has** to co-ordinate explicitly every subsequent change.

The PC should assess the impact of his/her clearances on the next receiving sector and avoid generating complex co-ordinations (with the help of the co-ordination problems and filtering applied to the flights in the ACI).

When he is aware of the chance to optimise a trajectory, the PC should not hesitate to achieve it, even if he has to co-ordinate it with the next receiving sector.

If changes planned on the trajectory impact the part of the trajectory before the sector, these changes **have** to be made by the giving sector.

If an action is required by the next receiving sector, it should, as far as possible be performed through a closed clearance, this is the only case where the TC gives a strategic clearance (if the ahead time is big enough), or he/she may delegate it to the PC.

3.5 Actual system running and impact on the experiment

[2] on the aircraft side, these strategic clearances are received as a trajectory change for the equipped aircraft (see : 3.2.4 "Main functions in the IOCP": the CPDLC "route clearance") or as a series of timely delivered tactical clearances for non-equipped aircraft.

No operational evaluation of the IOCP platform was performed prior to the training phase, so the assessment of its working order is based on synthesis of breakdowns and malfunctions observed during the experiment. Below is a brief description of platform shortcomings which may have had an impact on the experiment and an explanation of their origin.

3.5.1 Main sources of breakdowns

If we refer to the platform overview presented in section 3.2, the breakdowns which occurred during the experiment were caused by two major components only: the GHMI and DL communications. The other three components (Ground system, Advanced functions and traffic generator) were not flawless, but perfectly robust.

Unfortunately, GHMI breakdowns were quite frequent (an average of three by run and by sector) and relatively penalising (because they occurred, most of the time, when controller was "interacting", the breakdown interrupting an action). Moreover, all GHMI breakdowns caused the restart of the two monitors of the sector suite. In all cases, the GHMI was hot re-started within less than two minutes. As the rest of the platform was "frozen" (stop of simulation time), these interruptions had no direct impact on the level of workload and fluidity, but certainly influenced the controllers' concentration and their level of "frustration".

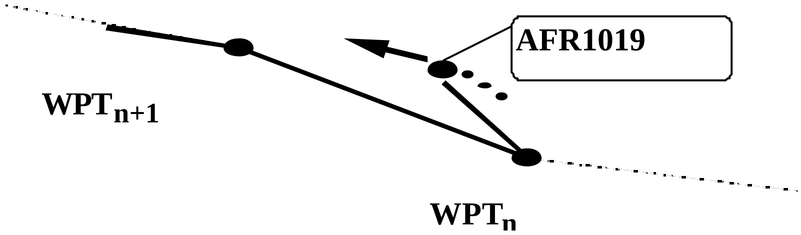
The DL communications breakdowns had a very different impact: either we chose to continue the simulation without DL (which was of very little interest, considering that 70% of the aircraft were supposed to be planned by DL), or we chose to stop the run and re-start it again from the very beginning. This, of course, had an impact on the way the traffic sample was handled on the second run (because it was already partly "known" by the controllers). No hot restart capabilities were available at DL communication level. DL communication breakdowns were rather frequent and penalising during the training phase, but only occurred once during the measured runs.

3.5.2 Main malfunctions

System overload causing delayed response time for trajectory update: one of the study major issue was anticipated trajectory editing, which means that the update of trajectories according to controllers' input was a very critical function. The update time (between controllers' validation action (or aircraft reply), and actual change in the system trajectory) was much too long (more than 1 min) as soon as the number of aircraft and the frequency of inputs reached a certain threshold. This had a direct impact on the controllers workload, because it caused much more monitoring demands: frequent checks of the edited flight to make sure that the requested trajectory was -at last- taken into account.

System overload causing loss of events:

- when progression over a waypoint was lost, it caused inconsistencies between the displayed trajectory (which was the actual input for the tools computation) and the aircraft position and heading given by the traffic generator,



- some edited trajectories appeared to be lost (this means that controllers' (PC) planned trajectories were never taken into account).
- some controller's inputs were lost and had to be re-input (especially the assume function).

Outdated starts of manoeuvre: as will appear below, in the "results" chapter, the trajectory editor was used by the Tactical Controller more often than expected, which induced some cases of short time ahead editing (start of manoeuvre too close to aircraft current position). When the complete cycle of dialogue with the aircraft was over, the start of manoeuvre was actually behind the aircraft position, thus causing the traffic generator guidance function to try and turn the aircraft back, with the same results as above ("random stacks").

Lack of relevance in CT filtering outputs: this had several consequences depending on the context. When the controller was analysing a conflict situation (problem oriented filtering), it appeared quite frequently that the filtering was too pessimistic, highlighting so called "contextual" aircraft, that didn't seem to have any relevance with the context. This had no direct impact on the way the traffic was handled, but caused a certain lack of efficiency. An other situation was when a conflictual aircraft was forgotten in a filtering: from the first it occurred, any controller completely lost his/her confidence in the system ... which can mean that the tool didn't help him/her any longer.

Lack of meaning of "interaction zones" displayed by the "quasi interactive what-if" planning aid when a trajectory was being changed: these "red segments" were too long, and very difficult to "erase" completely through a classical manoeuvre, so they were not really used as they were meant to be.

Some "non connection" or "connection ended" DL aircraft: some cases of individual DL aircraft "non connection" or "ended connection" also occurred, with no mean to start the connection again (five cases over the all runs). There was no direct impact on the workload, but a feeling of frustration: no anticipated planning could be done on these flights any longer.

3.5.3 Global evaluation of the impact

Of course, our description is very qualitative, because it was not possible to make a real time tracking of the malfunction, a more rigorous analysis would require watching again videos tapes (and only half of the positions were recorded for each run). A brief description of the malfunction observed during each run and of its impact is detailed in Appendix C: Table of measured exercises affected by technical deficiencies.

4. Trial method

4.1 Timescale

The IOCP experiment was conducted in two phases from 14 to 25 April 1997:

- training phase (first 4 days),
- measured experiment phase (6 days).

During the experiment phase, six traffic samples numbered from 212 to 217 were run. These samples were of a medium load (equal to today maximum capacity and lasted about 60 minutes).

At the end of the experiment, we ran exercise 218, which presented a higher traffic load (25% increase), this run was not meant to be measured, but we finally decided to include some of its results in the report (notably for quantitative data).

The planning of the IOCP experiment is detailed in Appendix E: Detailed Time table (training + runs).

4.2 Controllers

Four en-route controllers were drawn from CRNA Aix and from CRNA Bordeaux. As none of the controllers had experience in the relevant sectors, they were given an introduction to the simulated sectors (UR/UY and UN/XN from Reims). Two of them were familiar with some aspects of the HMI concept, having an experience with the ERATO Co-operatives Tools.

4.3 Runs and experimental variables

Here are listed the characteristics of the experimental situation (that is to say what was controlled at variability level), which we set to correspond to the objectives and constraints of the experiment:

- rotation of controllers within a position and from one control position to an other,
- similar traffic load for each traffic sample. The traffic load corresponds to the current maximum capacity per hour. At first, the objective was to study concepts in control activity (internal assessment) before performing an external assessment, as to show the concepts tend to go in the sense of an improvement of performances,
- a table of traffic load samples and complexity (as can be assessed through the number of PROSITs) is included in paragraph 10.4.4: "Problem resolution in the ACI" (see "distribution of traffic load"). Today's maximum capacity is equal to 40 for UR/UY and 42 for UN/XN ; the average load of UR/UY was 44 a/c per run for UR/UY (min: 37, maxi: 49) and 38 for UN/XN (maxi: 46, min: 31). The preparation of traffic samples is more detailed in Appendix B: Traffic samples preparation,
- no comparison of scenarios (no situation of reference),
- 70 % of "equipped" flights in all runs. As for the PD/3 final demos, the runs only contained two types of aircraft:
    - **the equipped aircraft:** 4D guidance and DL

* **non equipped aircraft:** 3D guidance and NO DL

4.4 Training

4.4.1 Experiment phase

Training was divided into five parts:

- initial explanation part: introduction to experiment context, IOCP concepts based on human centred approach, history of the project...,
- co-operative Tools main principles explanation,
- small directive exercises: this part was based on specific demonstrations built to introduce progressively each tool (way of use, operational use...). At the end, the controllers were able to manipulate the HMI,
- practice exercises with an increasing capacity,
- training questionnaire.

4.4.2 Training aim

The objective to be reached was to transmit to the controllers:

- a clear visibility of the objectives of the experimentation and of its limits,
- working method and use of HMI,
- acquisition of all dialogue modes,
- a know-how to be able to use procedures associated with the functions (using traffic samples).

A “light ” questionnaire at the end of the training phase allowed to assess the level of comprehension of concepts and acquisition of dialogues.

4.4.3 Human resources

Human resources were the following:

- 2 trainers for controllers: same persons as observers, i.e. the ergonomic experts ;
- assistance from the development team manager and the IOCP project leader during the practical sessions and briefings ;
- 1 trainer for pseudo pilot: the person who has specified or developed the pseudo pilot HMI ;
- 1 technical assistant acting as technical supervisor.

4.4.4 Training progress

Training was made according to the following schedule:

- Phase 1: = day 1
    - presentation of experiment context,
    - theoretical introduction of new concepts, presentation of general outlines of platform components,
    - presentation of the experimentation progress and of the observers' role,
    - acquisition of necessary knowledge of the airspace.
- Phase 2: ½ day = day 2

  - presentation of HMI principles,
  - presentation of the use of dialogue modes and information according to the tasks (sequential, parallel) determined in TLD.
- Phase 3: ½ day = day 2
  - know how to implement functions = training on mock-up using a very directive model of use (controllers have to learn how to use HMI and not to control),
- Phase 4: 3 days = day 3 -> day 5
  - training with traffic samples in directed mini-exercises,
  - use of pause function to explain and guide the controller so that he/she makes use of all what he/she has at his/her disposal.
  - final questionnaire (to have an idea of the acquisition level of concepts and tools and an evaluation of training methods).

4.4.5 Interactivity of "mini traffic samples"

In order to improve training efficiency, we proposed the controllers a series of very precise traffic samples. The aim was to help the controllers to get used to the tools in a very progressive manner, and in a sure and deepened way.

It seemed to be an interesting way to proceed. Nevertheless, the idea has to be deepened and enriched, because the controllers clearly express their desire to benefit from a training laying on a quick practice of the tools in relation to the theoretical explanations and demonstrations.

4.5 Measurements and data collection

4.5.1 Recording equipment

Recording equipment was composed of:

- 2 camcorders (1 for each position) to film and record a 2000x2000 screen for each position. The video quality allowed to see the use of the different HMI elements (manipulation of menus, trajectories, agenda... and movement of the cursor),
- 2 video monitors (for the videotaped briefing session),
- audio recording: to record PC/TC dialogues of the same position and dialogues between positions.

To perform the videotaped briefing session it was necessary to synchronise audio dialogues with the video.

4.6 Analysis methodology

The objective of quantitative data was only to help the experimenters to interpret the other data they collect for each run and possibly to constitute a “ database ” for future assessments. Because of the small amount of data and great amount of variables, no statistical test have been formulated.

For each measured exercise, a full set of objective and subjective data were gathered for analysis. The measures recorded are outlined below. Detailed tables of quantitative data processed can be found in Appendix F: Table of quantitative data.

4.6.1 Subjective data

The subjective data, i.e. the measures representing the controllers' opinion, were gathered through their comments, interviews and the use of questionnaires. The NASA Task Load Index (TLX) questionnaire was used during the experiment, but will not be exploit in an exhaustive way. Firstly, in this experiment, there was no baseline organisation to refer to. Secondly, the controllers had difficulties to understand the terms and their relevance in the context of their activity. For example, the distinction of meaning between terms like “effort ” and “ physical demand ” was not obvious. To answer the questionnaire, the controllers often had to be helped through examples referring to control activity. Having in mind that the number of data collected was very few and the problem of vocabulary understanding created a bias, we only observed the following general tendency: it seems that frustration, time pressure and mental demand were the main factors that had an influence on the controllers’ workload.

4.6.2 Objective data

The objective data were recorded automatically by the system. For example, files were produced containing the type of action the controller made or the type of event generated by the system (a PROSIT appearance, for example). Nevertheless, the way data collection was implemented did not always allow to proceed to some comparison (e.g. the comparison between the number of resolutions made for the equipped and non equipped a/c).

4.6.3 Observations

During training and trials, the controllers' behaviour was observed by ergonomic experts. The purpose of the observation was to record, subjectively, controller responses to events and the occurrence of certain actions. The video tapes allowed to collect interesting comments during the debriefing time after each simulation.

5. Trial results

The comprehensive experiment report, based on observations, interviews, recorded data and the questionnaire is in Appendix A: Trial results. Here after is a summary of the most important outcomes of the experiment.

These results presented in appendix are organised following the evaluation issues listed in Section 2. The major issues expected to bring an input to refine the final PD/3 demo scenario are also summarised in the second paragraph.

5.1 Main results of the experiment

This experiment has to be considered as a development evaluation, mainly aimed at refining the definition of the PD/3 en-route position (tools, user interface and working methods). To this respect, the following conclusions can be drawn:

- communications between controllers of the same position were increased. They were essential to keep the TC in the loop (Section 10.3.2) ;
- the fact that PC and TC could communicate with the pilot via DataLink or R/T might lead to confusion (Section 10.3.2); this has to be coped with in the guidelines and the training phase ;
- integration of flights appearing in PROSIT (potential conflicts) could not be put into practice as expected (Section 10.5.1); traffic integration should still be done flight by flight, but the planning controllers should be provided with strong guidelines to use the Activity Predictor information during integration ;
- datalink was beneficial to the controllers because it released the R/T for urgent messages and relieved controllers from mental workload (Section 10.5.2) ;
- the anticipated planning led the PC to anticipate according to the entire a/c trajectory more than to the sector that was crossed (Section 10.5.3) ;
- the possibility to make a continuous dynamic projection of the relative position of the aircraft via the PROSIT dragged along the time axis in the Activity Predictor was felt useful and easy to manage (Section 10.6.2) .

These results will enable to better prepare the final PD/3 demonstration.

As explained in detail in sections 10.2: "Performance, workload, user acceptance", and 10.6: "Operational quality of the experimented tools and aids", the actual setting of the experiment (length, training, tools and interface available) do not allow us to produce any measured benefit assessment:

- the absence of a reference situation prevents us from assessing objectively the influence of the prototype on fluidity (Section 10.2.4);
- the controllers considered they experienced too much difficulty in managing the tools to accept more traffic than today (Sections 10.2.1 to 10.2.3) ;
- the TEDI was not workable without a more interactive dynamic conflict display during the edition of a new trajectory (Section 10.6.1) ;

- effective anticipation through the use of the TEDI was not always possible because of its use constraints (Section 10.6.1) ;
- it cannot be said whether the complexity of the filtering function was due to the system defaults or its limited relevance (Section 10.6.3.2).

It is expected that the planned setting of the final demonstration will enable to overcome these limitations.

5.2 Detailed results about evaluation issues

5.2.1 Co-operation between controllers of the same position

The **task continuity** is essential to assure a common traffic image between the TC and the PC. Through the number of communications engaged, we noticed a strong need to share information which must be supported by the tools: the good point is that HMI did not limit communications between the PC and the TC but **communications were very numerous concerning: problem resolution and actions intentions in general, common solution elaboration, PRORES and PREPLAB context confirmation.**

Controllers first stated that operational instructions related to responsibility sharing were hard to apply and anticipated planning first caused some overlapping actions. However, at the end of the experiment we observed a more efficient co-operation as the controllers felt more familiarised with the tools. Task allocation became more clear and stabilised as described in the operational instructions.

The TC felt that with the offered assistance tools they lost the “ noblest ” and most interesting part of their work, which was a source of frustration. In some cases, their feeling of having only to “ execute ” instructions prepared by the PC was certainly emphasised by the lack of contextual information. This limitation has to be made for in PD/3: information about a PRORES context must be available to the TC.

5.2.2 Co-operation between controllers of adjacent sectors

The objective was to observe the co-operation between two adjacent control positions in an anticipated planning context. In the IOCP frame, no MSP has been simulated and inter-sector dialogues were not supported by the system, so the PD/3 concepts were present in a very limited way. Our major objective was to see whether providing ACI problems (which concerns the part of the trajectory after the aircraft has left the sector) enabled to alleviate co-ordination with the next receiving sector (thus enhancing anticipation).

Controllers stated that anticipated planning created an additive workload as it caused more communications between sectors. The PC tended to prepare long range clearances only when they were not too loaded because co-ordination was time demanding.

Controllers often complained about missing information whether or not the flight was already planned in the giving sector. This could induce re-planning for the same flight.

According to the controllers, PROSIT concerning conflicts in the **ACI** increased the information to take into account and were not always useful: the controllers had tendency to destroy them as soon as they appeared. That kind of PROSIT overloaded the APD for problems controllers could not necessarily resolve. Nevertheless, we observed that the controllers took these problems into account when, because of a problem occurring in their sector, they had to modify a trajectory of an a/c that was also involved in a problem in the ACI.

5.2.3 Anticipated planning

The concepts of anticipated planning and planning authority between positions were hard to assimilate. The controllers seemed to be satisfied with the proposed working methods concerning the sharing of flight planning authority even if these instructions were difficult to apply at the beginning of the experiment.

The PC criticised the fact that not all information about a flight plan was directly accessible: *"There is too much hidden information! On this IOCP platform, there is much information on which we don't have direct access, when today we do!"*.

When a new flight appeared, the PCs opened the extended label and flight leg, and then the filtered view (SIA) to check any conflict. Information concerning the planned trajectory (i.e. the flight leg) seemed sufficient most of the time to execute anticipated planning.

Most frequently used tools to get information:

- **when the flight was conflict free**, the PCs used the TEDI for optimisation or placed an alarm clock to plan a flight level modification (Team 1) or do nothing.
- **when the flight was not conflict free,** the PCs used the TEDI filtered view (to see the red potential interaction areas). They eventually consulted the APD by opening extended PROSIT and using the extrapolation function from the PROSIT.

We sometimes observed confusions caused by not taking into account the a/c equipment (through not paying attention). However, we noted a strong **DataLink** benefit for controllers (it relieved controllers from their mental workload: " *The work is done with DL a/c whereas with the no DL a/c, you have to check if the TC actually sends the instruction by VHF* ").

The PC preferred to handle equipped a/c because they required less peculiar actions and demanded a lower workload (no need to supervise the TC for sending, ...). The PC had the feeling of a work "done " when preparing equipped a/c trajectories. This was more comfortable for the PC.

Equipped and non equipped flight were generally processed the same way for conflict resolution.

On the other hand, controllers **preferred making optimisation for DataLink equipped aircraft** because it was easier to manage (no PREPLAB implies no communication between controllers and supervision for validation).

5.2.4 Operational quality of the experimented tools and aids

We specially focused on the assessment of utility and usability for the main tools and the following functions:

- TEDI,
- APD,
- filtered information,

- **TEDI (Trajectory editor)**

Controllers stated that TEDI use had to be improved to be workable. At the beginning, they had a lot of difficulties, but they use it better and better (although TEDI suffered from many system limits and difficulties to use).

We observed that the use of the TEDI encouraged long range clearances (manoeuvre starting point often located before the sector and the resume point much further than the exit boundary).

The operational guidelines stated that the editor was a PC tool in priority, but it seemed that the TC tried to use it more often than foreseen, especially when he/she had to integrate the flight and had nothing else to do.

The offered tools ease the trajectory planning: direct "send " to board for equipped flights was very well accepted by controllers as an efficient way to decrease workload. However, we have to note the negative impact: **manipulating a graphic object causes a loss of flight identification.**

Controllers felt that TEDI would be more useful with a dynamic visualisation of potential conflicts when editing the new trajectory.

- **APD**

PROSIT was used more as a conflict "aide memoire" function than as a conflict detection aid.

Controllers systematically displayed extended PROSIT when they were in the middle of the APD (not as soon as they appeared). **PROSIT extended function, displaying the list of callsigns of the aircraft involved in the problem was always used because it gave the needed information.**

The PCs pointed the cursor on every PROSIT involved flight (it was easier that way to locate the a/c individually). The PCs used the highlighting facility associated with passing the cursor on the PROSIT: given the great number of already existing codings, this attracted their attention better than a "fixed" coding .

The PCs consulted the extrapolation function from the PROSIT. This was really helpful to decide on which flight to act. The extrapolation function was easy to use with the PROSIT and very appreciated by controllers.

The APD was often used to make up for delay on conflict detection after an overloaded period (often due to the use of the trajectory editor). Controllers proceeded in two steps:

- a grouped consultation of conflict labels when they have time enough ;
- a "cleaning" of the APD.

If the PC concentrated too much on the APD, he/she lost traffic notion. This was also caused by the general working method guidelines, which prompted the controller to integrate the traffic through the APD. This guideline has to be amended, as explained in section 7.1: " Feed back on the IOCP concepts".

From an HMI point of view, unfortunately, the APD overloads the screen. **According to the controllers, the APD should be placed on another screen, but this opinion must be**

handled with care, as it is partly due to the major role given to the Plan View Display in today context.

- **Filtered views**

The SIA filtered view was the most used because it was the simplest to understand (this filtered view did not contain too much coding).

Controllers had difficulties with **the STU filtered view** because codings were too complex (plus the technical limitation caused by the lack of relevance of interaction red segments).

Critics related to filtered views were as much linked to the concept as to the implementation defaults (colour coding to be revised, interaction areas detection reliability to improve...).

Nevertheless, filtered views allowed to use the extrapolation function (especially by the means of PROSIT labels in the APD) which was quite straightforward and could help to take a decision.

The feeling of a "fragmented perception" of the traffic conveyed by the use of filtered views must be addressed with care. the APD should also be presented as a way to avoid "filtering focusing" thanks to the general traffic image it offers.

The controllers felt that the filtering functions HMI have to be more efficient: avoid having different access to trigger the same filtered view and reduce the number of colour codings.

6. Lessons learnt

6.1 Following up the experiment (ergonomics experts)

6.1.1 Evaluation and data analysis tools

The following comments can be done:

- video replay requires a good equipment and a qualified person to operate it in an efficient way (in addition to ergonomic experts, who are very busy with their real time observation activity),
- traffic samples scripts must be integrated into observation tables,
- re-visualisation (self confrontation) should be carried out wisely, because it may be an extra source of tiredness after simulations. Moreover, this support is well manageable only if experimenters are correctly trained to control and use the experiment platform,
-
- recorded data must be aimed at the experimental protocol and recording tools must be designed jointly by the development team and the experimenters team.

6.1.2 Quick evaluation feed back

At least a half-day is necessary to make a general analysis of the results.

6.2 Controllers training and operational guidelines

6.2.1 Training phase organisation

The following comments can be done:

- **one week of training is insufficient**,
- controllers must manipulate tools earlier in the training phase, combining theoretical aspects and practice of the HMI, to learn that, they need to be provided with limited "training scenarios" with reduced traffic cases, or, even better, with reduced versions of the HMI.

6.2.2 Importance of operational guidelines

During the IOCP experiments, we tried to achieve a compromise between:

- to provide the controllers with a comprehensive working method,
- to let the controllers find an efficient way of exercising their know-how through explaining changes with regard to today's methods (the major points being: anticipated planning of trajectories (causing new balance of responsibilities and new task sharing), working in a problem driven approach (instead of flight by flight) and taking into account areas of common interest.

One of the aims of IOCP experiments was to assess the feasibility of the En-route control position and to **refine** the working methods associated with the Co-operative Tools, this is one of the reasons why we didn't impose rigid methods[3].

If we want controllers to use the new tools, they must be provided with straightforward -not arguable- "rules" from the very beginning of PD/3 pilot phase. Provided that PD/3 vocabulary is understood without ANY ambiguity by controllers, the shorter guidelines would be, the better! (let's take 150 words as an objective). The problem of having a common vocabulary is mentioned several times in the report and should not be forgotten during the training preparation.

An example of guidelines we would suggest for the PD/3 En-route position is provided in the second part of Appendix D: Working methods guidelines.

6.2.3 Guidelines about traffic integration

The planning controller must be better supported in taking traffic into account on a "problem basis". He/she must have a "flight oriented" check list somewhere and use the Activity Predictor as a support to assess the flight context faster and more efficiently.

One of the IOCP objectives was to see whether controllers (especially planning controllers) could manage the situation on a "problem" basis (instead of flight by flight). Guidelines thus prompted the planning controllers to deal with "problems" in priority, and then to use the SIL as a check list, to be sure that they had scanned all the flights. This resulted in having planning controllers managing the SIL, thus depriving tactical controllers of a support that would have enabled him/her to make sure that he/she had taken every flight into account before its initial R/T contact. In PD/3, the management of SILs is different and remains in the hands of the tactical controller, which is good. An idea could be to flag the flights already taken into account[4] by the planning controller in the SIL so that he can still use them as a check list.

Although this recommendation is at a relatively low level, this point must be tackled with care, because a successful traffic integration is the key to an efficient memorisation and traffic awareness.

6.2.4 Guidelines about Planning authority and Control authority

[3] The other two reasons are the incompleteness of the system (no support for inter-sector co-ordinations) and the reduced training time (let the controllers find and memorise their own methods was assessed more efficient than starting a whole training from zero).

[4] A flight would be considered as taken into account, as soon as a PC would have used the EDITOR on it (either in DISPLAY or EDIT modes)

The concept of "planning authority" first caused rather strong reactions[5] but was relatively well accepted by ATCOs at the end of the training. Nevertheless, and though the level of informal team communication seemed to be satisfactory, it also seemed that ATCOs expected more support from the system to clearly share the work.

A recommendation for PD/3 would be either to have PC or TC oriented HMI functions (which may cause a loss of flexibility) or to insist more on a strict sharing of the roles in operational guidelines and during training.

6.2.5 Guidelines about system update in case of immediate clearances

To enforce this decision, in cases of immediate clearances, system updating must be eased as much as possible and the necessity of updating the system as soon as a tactical clearance is issued must be stressed in detailed guidelines. This is mentioned because ATCOs were sometimes frustrated to issue immediate clearances by R/T (and still have to feed the ground system) whereas strategic clearances could be input by DL (feeding the ground system at the same time).

NOT sending immediate clearances by DL (except Frequency Change) must not be put into question, because it would complicate the handling of mixed traffic (without any benefit for the main evaluation issues of PHARE).

6.3 System and facilities limitations

The following comments can be done:

- radar display is too small[6],
- system response time has to be shorter,
- system information processes (tools usability) have to be improved to be less constraining,
- once the trials started, software modifications should be avoided (not to introduce biases).

[5] the most resented aspect is the fact that clearances can be sent without even giving any notice to the TC of the sector where the flight will be impacted.

[6] Although it seems difficult to bring any improvement, this is mentioned as a CENA specificity: on the controllers' working position, the 2000/2000 screen is further from the controllers than in some other partners' set up, and then "looks" smaller. That led us to use bigger fonts.

7. Conclusion and orientations for PD/3

7.1 Feed back on the IOCP concepts

It is still difficult to sort out what is due to imperfections of simulation environment (including training) and what is due to advanced functions and their interface. **Filtering and "problem situation" are new concepts and they should be addressed with care, notably through a well adapted training** (working problem per problem instead of flight per flight disrupts the memorisation process).

On the other hand, **making a continuous dynamic projection of relative a/c positions involved in a problem is felt efficient for risk assessment and using PROSITs with a time and inter-controllers transfer management support (APD) seems to enhance PC/TC communication (thus TC involvement)**.

The concept of Area of Common Interest and displaying filtered views at sector boundaries (to alleviate co-ordination with next receiving sector) didn't prevent an increase of co-ordination between sectors. We think this is partly due to a lack of anticipated planning; as planning controller didn't always succeed to plan "on time", many cases of *explicit* co-ordinations were observed, whereas they should have been *implicit*. The heavy co-ordination workload is also explained by the lack of system supported co-ordination.

The concept of anticipated planning was rather well accepted after a while, but not put into practise as often as expected; the Highly Interactive Problem Solver is expected to bring a significant improvement.

7.2 Feed back on the evaluation method

PHARE is a proposition for an "Air/Ground integration" operational scenario. In quantitative terms, we will consider this scenario interesting to explore if tools and working methods proposed in demonstrations allow to handle a significant traffic increase. On the qualitative plane, we aim at maintaining a safety level at least equivalent to current situation.

It is difficult to measure a safety level empirically -for obvious reasons, related to the context of the simulation- but also because of the impossibility to apply statistic laws to a limited amount of simulations. That is why, a method of indirect measure was privileged, which is the controllers easiness to apprehend and deal with a traffic situation with the tools we gave them. The question is to assess the performance of the global Human/Machine system. This assessment can be performed through subjective data (controllers' feeling) or objective data (observation and measures).

The subjective assessment: during our experiments, we have rather privileged straight judgement of controllers. This is the major source for the results presented in the report; we also experienced some difficulties in using TLX (e.g. section 4.6).

The objective assessment: profiles of traffic samples can be compared with the way simulations took place. **The samples included a sustained amount of traffic** (equal to the current maximum capacity of the simulated sectors) **and an increased complexity** (artificial introduction of additional problems).

Sometimes, on the most loaded sector, the planning controller appeared to be close to saturation (two rather critical moments over the six measured simulations). At those moments, the tactical controller was also working in non-optimal conditions (and his/her difficulties seemed due to delay of the PC). We want to emphasise that the seventh simulation, which showed an 25% increase of traffic (with no artificial complexity), seemed to be better than previous simulations. This observation well illustrates how ambiguous it may be to express experiment results only in terms of traffic increase.

7.3 Which orientations for PD/3?

Final demonstrations, with a more comprehensive scenario involving multi-sector planning, should not compromise the positive points (projection in time of a filtered situation and PC/TC communication). The filtering function still has to be tuned carefully, to come to a satisfactory set of contextual aircraft.

With the limited set-up of the IOCP, it was impossible to define the exact reasons for bad performance (e.g. bad conception of tools, functions, difficult, insufficient training, technical limitations of the simulation environment...). One thing that is certain is that for the final demonstration, it will be necessary to provide a more satisfactory training.

Moreover, the user interface and software platform should be increments of the current versions. In that way, we can hope for a reduction of the impact of the technical limitations on the conclusions of the experiment.

Inevitably PD/3 will be limited in scope and time, this means also limits on the validity assessment of gain in capacity resulting from such an exercise. Moreover, we attach great importance to the demonstrative dimension: identifying the conditions in which part of the operational scenario works properly, will help each PD/3 site to evaluate the impact on his part of the concept.

8. Glossary

a/c	:	Aircraft
ACI	:	Area of Common Interest
AFL	:	Actual Flight Level , the Mode C level of an aircraft on the RPVD
APD	:	Activity Predictor Display (or AGENDA ; " CT concept ")
API	:	Application Programming Interface (OSI)
ATCO	:	Air Traffic Controller
ATN	:	Aeronautical Telecommunication Network
CENA	:	Centre d'Etudes de la Navigation Aérienne
CFL	:	Cleared Flight Level, abbreviation and field in aircraft radar label
CMS	:	Common Modular Simulator
CPDLC	:	Controller Pilot Data Link Communications
CRNA	:	Centre Régional de la Navigation Aérienne (French ACC)
CT	:	Co-operative Tools
DL	:	Data Link <equipped>
DAARWIN	:	Distributed ATM Architecture based on RNAV Workstations Intelligent Tools and Networks
ERATO	:	En Route Air Traffic Organisation
ETMA	:	Extended TMA
FMS	:	Flight Management System
GHMI	:	Ground Human Machine Interface
HCA	:	Human Centred Approach
HMI	:	Human Machine Interface
IOCP	:	Internal Operational Clarification Project
MASS	:	Multi Aircraft Simplified Simulation
MSP	:	Multi Sector Planning
OTF	:	Operational Task Force
PAT	:	PHARE Advanced Tool
PATN	:	PHARE ATN
PC	:	Planning Controller
PD3	:	PHARE Demonstration 3
PHARE	:	Programme for Harmonised ATM Research in EUROCONTROL
PREPLAB	:	PREParation LABel

PRORES	:	PROblem RESolution
PROSIT	:	PROblem SITuation
PVD	:	Plan View Display
RES	:	RESolution
RFL	:	Requested Flight Level
RPVD	:	Radar Plan View Display
SIA	:	Set of Interfering A/C
SIL	:	Sector Inbound List
STCA	:	Short Term Conflict Alert
STU	:	Significant Traffic Unit
TC	:	Tactical Controller
TEDI	:	Trajectory Editor flight Interaction
TFL	:	Transfer Flight Level
TLD	:	Task Logic Diagram
TLX	:	Task Load indeX
TMA	:	Terminal Manoeuvring Area
TN	:	Trajectory Negotiation
TP	:	Trajectory Predictor
TST	:	Trajectory Support Tool
UAC	:	Upper Airspace Control
Wilco	:	Will comply
XPT	:	eXit PoinT of the sector

9. References

[1] CENA/NR97-016, IOCP step 1b - Experimental Protocol - General Definition, N de Beler, December 96.

[2] CENA/NR97-017, Protocole expérimental de l'IOCP step 1b ; Protocole détaillé, N. de Beler, C. Chabrol, I. Coullon, Avril 97.

[3] CENA/NR96-272, PD3/IOCP step 1b: MMI spécification, version 2.0.

[4] GHMI Specification for PD3 -Part 1- PD3 Controller Task Logic. PHARE/NLR/GHMI-6.9/WP1 ;1.0 Draft. August 96.

[5] PD3: Release to IOCP 1b: MMI specifications, CENA DRAFT, Joël Garron, Mars 1997.

[6] PHARE/NLR/PD3-1.3.1/WP1 PD/3 IOCP programme document

[7] CENA/NT.96-560 HCA IOCP: Functional specifications

10. Appendix A: Trial results

10.1 Result limits

In looking at the results, the following problems need to be taken into account:

- training problems: too short duration and system problems during training phase had consequences on training efficiency. Performing a training program as preliminary defined in the protocol was not fully applied,
- technical problems during the simulations rose incoherent information (too long HMI response time, some flights U turns, etc.).

Although the system performance got better in the course of the experiment, these problems prevented controllers from fully getting used to the tools.

In the following pages, the word " team " indicates a controllers suite (a PC and a TC).

Concerning the questionnaire, not all controllers systematically answered all the questions. For this reason, the total answer number does not always correspond to four answers per question.

10.2 Performance, workload, user acceptance

(See Reference [1] - External Topic 1: Performance and Safety).

Here we report the data collected to demonstrate feasibility and operational implications of new tools introduced in control activity. Our purpose was to evaluate whether HMI and working methods proposed (based on the Co-operative Tools and anticipated planning) facilitated or limited the global system performance (including capacity, safety and fluidity).

We present the results concerning the controllers' feeling of workload and performance achieved which give an indication on tool acceptance and comfort.

10.2.1 Quality of control and satisfaction of the work done

Observations and interviews:

Generally, during the simulations, controllers were fairly well satisfied of the work they did, taking into account their current state of knowledge and understanding of the system:

- they felt it represented a strong rupture with their current working methods: completely learning working methods with the tools proposed could not be obtained in only two weeks,
- they felt that control instructions made according to the tools and given experimental operational instructions were not always the most efficient (give heading clearance instead of level clearance for example),
- they would like HMI usability to be improved (lot of frustration, loss of time due to HMI limits). See chapter 6 on operational quality of tools and aids,
- they considered HMI functions difficult to learn (too many different functions),

- the technical problems of the system during simulations prevented from performing control with a good level of quality.

Questionnaire:

- Working methods and tools proposed (trajectory editor, APD...) allow to perform control of good quality.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	2		2		

To our point of view, the heterogeneity of the answers shows that the tools were too new and the usability problems were too important.

10.2.2 General feeling about workload

Observations and interviews:

Controllers often felt that the tools offered tended to increase workload in comparison to the actual situation. This additional workload was often associated to:

- difficulty to use tools:

" Too much delay in manipulating the tools which caused workload "

- additional tasks:

" The PC has to check if the TC has taken into account the PRORES which caused workload "

" The PC has to check if the DL aircraft takes into account the instruction given "

- lack of relevance and performance of the system aids which induced more load trying to understand and to accomplish the work.

10.2.3 Safety and workload

General comment:

Even if the data collected did not allow us to conclude to a safety improvement (airmiss and potential conflicts were not measured through a STCA), the offered tools and aids were not rejected by controllers from a safety viewpoint.

The experiment showed that when some controllers felt that they did not always respect safety norms in all simulations, they explained that it was more because of the workload caused by a lack of usability of tools (bugs) than because of the concepts themselves.

10.2.3.1 Safety and Conflict Detection Tools (planning and resolution aids, APD)

Observations and interviews:

PC

The PC often felt that with the offered tools they could not control well anymore what happened in real-time on their radar image, which gave them a strong feeling of insecurity. The conflict detection tools (APD, filtered views ...) caused a loss of global vision of traffic because of the mental workload and time demanded to use them and interpret advanced information.

However, in spite of this feeling, the PC seemed to manage the control with safety, even if this “ *fragmented vision* ” of traffic felt uncomfortable to them.

The PC often felt that the conflict detection was not workable. They often complained that the system did not always detect potential conflicts where controllers could do. System conflict detection was often considered either too pessimistic or too optimistic by the controllers. This lack of relevance of conflict detection led to a lack of confidence in the system (even though they were very positive at the beginning) and to an additional load: as they could not fully rely on the system, they tend to make their own conflict detection without any help of the system.

However, we observed some situations for which controllers were obliged to rely on the PROSIT proposed by the system: when they lost traffic vision because of focusing on tools. In that case, system conflict detection was useful even if it was of less comfort for them.

TC

The TC felt very uncomfortable not to integrate systematically the aircraft as soon as they arrived. The lack of integration (like the SILs validation for the PC) prevented them from making their traffic representation and well control the situation.

Quantitative data:

For each exercise, we calculated the number of PROSIT in the APD/number of PROSIT having exceeded the time limit.

Concerning the number of PROSIT, we found that:

- globally, there were more PROSIT in the UR/UY sector (313) than in the UN/XN sector (263).

Concerning the number of PROSIT in time limit, we found that:

- the proportion varies:
  - according to the experimented sectors: 35 % of PROSIT exceeding time limit for UN/XN, 27 % for UR/UY,
  - according to controllers: 25 % for Team 1 and 35 % for Team 2.

When the exercise was very loaded (Exercise 216: 75 and 91 PROSIT), a more important number of PROSIT exceeded the time limit.

We can say that training and working methods influenced PROSIT consultation.

Number of PROSIT (N(PROSIT)) / Number of PROSIT arrived in time limit (N(PROSIT) LT): (these data are given in more details in a per run, per sector basis in Appendix F: Table of quantitative data)

	UN/XN	UR/UY	Team 1	Team 2
N(PROSIT)	263	313	275	301
N(PROSIT) LT	91	85	70	106

Proportion	35%	27%	25%	35%

Questionnaire:

- Filtered views (SIA, STU) allow to handle traffic safely.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	1	3			

- Filtered views (SIA, STU) well supported conflict detection.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
		1	2	1	

✍ Comments: *manoeuvring flights were not well taken into account*.

- Filtered views (SIA, STU) supported well conflict resolution.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	1		2	1	

✍ Comments: *when red conflict areas were workable: the uncertainty was too important (length of the red areas, calculus of conflict detection...) to help the controllers efficiently.*

- It was possible to keep well separated aircraft .

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
				4	

The answers tend to show that more loaded traffic samples should be experimented to test a situation for which controllers would necessarily need to be helped by tools.

10.2.4 Trajectory optimisation and fluidity

General comment:

The four controllers stated that experimented new tools would not allow to enhance traffic fluidity.

“ We do not believe that proposed tools will be able to accept more traffic than today, because these tools are hard to manage and do not decrease workload ”.

Once more, the most relevant negative points collected were more related to the usability of concepts than the concepts themselves.

It is difficult to state the impact of Co-operative Tools and anticipated planning on fluidity through the collected data. The controllers did not have enough practical experience of tools and HMI was sometimes too incomplete to measure the impact.

Remark: Given the experiment limits, obtained results do not allow to evaluate objectively the prototype influence on fluidity. For this reason, a protocol should be defined comparing results obtained in a reference situation (current control) and an experimental situation.

Observations and interviews:

PC

When their workload was not too high, we observed that the PC tended to prepare optimised trajectories more for DataLink equipped aircraft than for non DataLink equipped aircraft which caused additional work for the TC as it created a PREPLAB on the TC's APD. They were aware of this consequence.

TC

Most of the time, the TC executed PREPLAB created by the PC to optimise trajectories. This often caused communications between both controllers (from TC to PC: explanation request, disagreement).

The TC did not seem to make any difference between PREPLAB related to optimised trajectories and PRORES related to conflict resolution.

We observed that the TC sometimes gave optimised trajectories to non DataLink equipped aircraft either with TEDI or menu (for an aircraft in the sector with an immediate instruction). But, in this case, the TC overlapped the PC's role which could have the following consequences: parallel use of tools, parallel instructions to board.

The TC seemed to give less optimised trajectories for non DataLink equipped aircraft because it meant additional work for him/her (VHF).

Quantitative data:

Distribution of the traffic load (Samples N° 212 to 217): here is presented the detailed account of flights on each sector and for each sample proposed in comparison with the number of PROSIT.

Exercises	Number of flights crossing UR/UY	Number of flights crossing UN/XN	Number of flights crossing UR/UY & UN/XN	TOTAL	PROSIT on UR/UY	PROSIT on UN/XN	Total Number of PROSIT
N°212	26	11	20	**57**	24	13	**37**
N°213	28	24	9	**61**	36	27	**63**
N°214	22	21	21	**64**	28	36	**64**
N°215	17	23	23	**63**	34	38	**72**
N°216	22	15	27	**64**	91	75	**166**

N°217	28	15	21	**64**	41	29	**70**
TOTAL	**143**	**109**	**121**	**373**	**254**	**218**	**472**

This table deals with theoretical capacity which did not necessarily represent the real capacity.

We observed that UR/UY had few a more PROSIT than UN/XN. Three factors could explain this difference:

- The sector configuration (UR/UY has crossed flow),
- UR/UY was crossed by more aircraft than UN/UY.,
- UR/UY served UN/UY and might have resolved conflicts which did not appeared on UN/UY.

Questionnaire:

- In the control room, with similar traffic, I would not have obtained such a good fluidity.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2	2				

Comments: *Not enough practical experience of tools:*

- response time longer than today,

- more workload (linked to the use of tools).

10.2.5 Working position

10.2.5.1 Display

- **Radar display size**

All controllers agreed the radar display was unworkable for anticipated traffic visualisation.

The controllers insisted on the fact the radar display was far too small and its rectangle size would not be adapted to oblong format sectors. They found the APD window reduced its size. Workload was increased because controllers constantly had to move the radar display off centre of the screen. They complained about the lack of an automatic " centring back" function.

CONTR SUGG: use only one column in the APD in which PROSIT, PRORES and PREPLAB are chronologically visualised.

- **Screen brightness and character size**

Character size also appeared to be too small which was disturbing and caused an eyestrain especially for the two female controllers.

- **Automatic label anti-overlapping system**

Controllers stated that the automatic label anti-overlapping system had to be improved.

Many entry mistakes or a/c confusion were caused by a bad positioned label.

- **Label information**

Some controllers found the nominal labels too full of information which tended to overload the radar image.

CONTR SUGG: some controllers proposed to visualise permanently only three pieces of information: callsign, AFL, destination. Other information (CFL, TFL and exit point) could only be visualised on the extended label.

- **Current time**

Some controllers mentioned that current time had a bad position on the screen.

CONTR SUGG: put the current time on the lower left corner of the screen.

10.2.5.2 Dialogue devices

- **Mouse**

After a certain time of training, the mouse was well accepted even by those who were not used to it (Team 1).

- **Menus**

The modalities of entering data were often considered difficult to succeed. (see section 10.7: "System updating").

ERG SUGG: Provide easier procedures to use menus.

- **Left handed controllers**

Left handed controller working position was not a topic of evaluation in this IOCP experiment. Nevertheless, this point will have to be taken into account for further developments.

As dialogue devices (mouse, telephone) were placed on the right side, left handed controllers felt less comfortable with this working position.

ERG SUGG: integrate the global working position in the next studies.

10.3 Co-operation between controllers of the same position

(See reference [1] - Internal topic 2: Assistance to co-operation between PC and TC)

This part deals with the evolution of task sharing between PC and TC of a same control position induced by the introduction of assistance and the proposed working methods.

10.3.1 Traffic image and task continuity

General comment:

Through the number of communications engaged, we noticed a strong need to share information between the TC and the PC and therefore appeared a lack of tools.

The TC often lacked information on the context and causes related to a trajectory modification. To keep traffic image and ensure task continuity, numerous communications between the TC and the PC were required.

This IOCP mock-up did not provide enough functions to share information between both controllers.

As the PCs rarely used the PROSIT automatic transfer to the TC (-6'), time limit seemed to be well adapted .

Observations and interviews:

- **PC**

The PC did not always have time to integrate the new flights and make him/herself an accurate traffic image because the use of tools monopolised his/her attention.

The PC, after having created PRORES, PREPLAB and alarm clocks, kept an eye on the TC to check if he/she validated them well.

- **TC**

The TC often complained having too few contextual information of an instruction and the reason why the PC decided to do so. We recorded many conversations linked to instruction context and confirmation requests on the proposed instructions (PRORES/PREPLAB).

The TC seemed to prefer asking the PC rather than using the tools at his/her disposal.

The symbology provided was sometimes badly understood or ambiguous for the TC (for example: the direct trajectories symbol which was an arrow).

The TC did not know if the PC already consulted the PROSIT visualised on his/her APD and to know if the PC resolved it (PROSIT appears in blue only on the screen of the one consulting), which induced more communications.

Traffic image seemed to be different for both controllers: with the offered tools, the TC could not get the same quality of image as the PC. This is explained by the lack of an integration task.

The TC had no means to know if the absence of planning mark on the label meant the PC had not planned the flight yet or if he/she had chosen not to plan anything for it.

ERGO SUGG: a planning mark or a different coding has to be displayed even if the PC did not make any modification to show that he/she actually saw the a/c without planning anything for it.

Quantitative data:

In all the exercises, the number of PROSIT arrived in time of transfer without the PC having made any action on them, is constant independently of the controllers, the sector and the number of PROSIT for each exercise, that means around 24 % of PROSIT.

Number of PROSIT (N(PROSIT))/ Number of PROSIT automatically transferred (under Transferred Time) without PC's previous action (N(PROSIT) TT):

(these data are given in more details in a per run, per sector basis in Appendix F: Table of quantitative data)

	UN/XN	UR/UY	Team 1	Team 2
N(PROSIT)	263	313	275	301

N(PROSIT) TT	62	77	67	72
Proportion	24%	25%	24%	24%

Questionnaire:

- **As a PC,** the task sharing with the TC corresponds with a logical working method evolution.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
			1	1	2

✍ Comments: I*t all depends on the sector.*

- **As a TC,** the task sharing with the PC corresponds with a logical working method evolution.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
				1	2

- **As a PC,** I had a clear and precise traffic image during the trials.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2		1	1		

✍ Comments: *HMI manipulation: difficulty to memorise traffic causes delay*.

- The agenda is a good means of presenting preparations made by the PC.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
		1		2	1

10.3.2 Sharing Responsibility

General comment:

The task sharing tended to improve with familiarisation degree of controllers with their environment. Controllers stated that operational instructions linked to the proposed working methods were hard to respect.

At the beginning of the experiment, we observed:

- a very hazy task sharing with overlapping between the TC and the PC. Task sharing was very flexible and dependant on workload: if the load was low, the TC tended to realise tasks belonging to the PC and the TC had difficulties to work 10 minutes in advance. As the PC got the same tools as the TC, he/she tended to do the same tasks,
- the standardisation enabled them sometimes to act in an isolated way (which brought drawbacks as well as advantages).

At the end of the experiment we observed a more efficient co-operation as the controllers felt more familiarised with the tools. Task allocation became more clear and stabilised as described in the operational instructions.

The proposed system did not seem to support sufficiently the task sharing defined in the operational instructions

ERG SUGG: provide functions to support sufficiently this need of information between both controllers defined in the operational instructions.

Observations and interviews:

<u>Task sharing and workload</u>

The PCs stated that the PC's role required more cognitive resources than the TC's role. Workload seemed to be deported on the PC.

<u>PC's main tasks</u>

The PC worked on two different time scales:

The PC worked in advance:

- upstream conflict resolution,
- flight integration,
- traffic planning,
- entering and exiting conflict resolution...

and also in real time:

- warning role: to inform TC of trajectory modification, to remind TC to assume aircraft and to clear flight level, to check whether PRORES and PREPLAB have been sent on board, to alert the TC on particular events,
- co-operative role between the PC of the adjacent sector and his/her TC.

<u>TC's main tasks</u>

The following tasks were allocated to the TC:

- mastering tactical aspects (shoot, assume ..),
- intervention on problems that still have to be solved,
- intervention in case of emergency,
- potential new flight planning,
- to contact pilot and transmit instructions the PC prepared (concerning non equipped flights).

In the simulated traffic samples, the TC workload was less important because often the main part of the work has already been anticipated by the PC.

<u>Experienced TC's role</u>

The TC felt that with the offered assistance tools they lost the “ noblest ” and most interesting part of their work which was source of frustrations. **They had a strong feeling they only had to “ execute ” instructions prepared by the PC.**

“Being a TC is very irritating ! I do nothing, I do not detect conflicts, I do nothing else than execute ! And I am not in the traffic any more because I am passive ! I do not have a good image of the traffic ! I do not always agree with PC resolution instructions ! ”

Nevertheless, during more loaded traffic periods we noticed several times the PC asking the TC to update the system.

The TC should only intervene in a degraded situation, but he/she badly accept the “ executing ” role in which *“ every thing leads you to leave things ! ”.* Consequently, the TC intervened in tasks also allocated to PCs (planning anticipation and integration above all).

<u>Communication between TC and PC</u>

The HMI did not limit communications between the PC and the TC but communications were very numerous concerning: problem resolution and actions intentions in general, common solution elaboration, PRORES and PREPLAB context confirmation (partly due to the limited confidence in the system).

These communications were essential to keep the TC in the loop.

ERG SUGG: implement some system functions to decrease the load related to communications (especially to avoid doubts on who does what).

<u>PC-Pilot communication through DL and their confusions</u>

With the offered HMI, both controllers could communicate with the pilot: either by DL (PC and TC) or VHF (TC in case of emergency).

We observed two different cases of direct instructions sent by the TC and the PC at the same time by different means. The TC sent a Direct to an equipped a/c while the PC was sending a trajectory via the trajectory editor. The TC, supervising the a/c, was surprised to see it did not follow his/her instruction!

This raised a priority question of orders: which instruction to follow? How to manage these problems related to the PC/TC’s standard positions?

ERG SUGG: this observation leads us to the fact that we have to decide which of the instruction is the most relevant. The problems linked to module standardisation have to be managed as well to prevent errors.

<u>Parallel use of tools</u>

We noticed a strong flexibility in task sharing that induced parallel use of tools.

When workload was low, we noticed that controllers overlapped their roles: the PC solved inter sector problems with TEDI or gave direct trajectories to flights located in the sector although the TC sometimes anticipated resolutions.

The TC had tendency to use the TEDI, this tool is the PC’s preferential tool, leading to a sticking of the PC’s TEDI if there was a parallel use.

ERG SUGG: this particular problem has to be managed to prevent confusion. For example, a specific coding could be developed to show that one of the controllers is working on the flight.

Quantitative data:

- **PC's actions**

The TEDI filtered view function was more often activated by the PC than by the TC: 527 TEDI activations for the PC Vs 337 TEDI activations for the TC,

The PROSIT consultation and resolution: the PC consulted more often the PROSIT than the TC did: respectively 399 Vs 161. With a few exceptions, the PC made the resolutions: 147 resolutions made by the PC Vs 59 made by the TC.

These three functions were normally assigned to the PC according to the task sharing proposed. The controllers well respected the instructions.

- **TC's actions**

The TC made 563 *assume* actions, 449 *shoot* actions and he/she *validated* 77 *resolution or optimisation instructions*. Carrying out all these functions represented 50% of the TC's HMI actions.

- **Actions shared by the PC and the TC**

Consultation of the extended label (the extended label contained complementary flight plan information in a label accessible with a single click on the label's icon): the number of consultations of the extended label by the PC was regular from one exercise to another. Concerning the TC, it varied a lot, globally, he/she consulted more often the extended label than the PC: 495 consultations for the TC Vs 356 consultations for the PC. The TC was more concentrated on the radar display with all its functions than on the APD.

Number of total functions carried out through all simulations: (these data are given in more details in a per run, per sector basis in Appendix F: Table of quantitative data)

FUNCTIONS	TC	PC
Flight Integration	37	267
Extended Label	495	356
PROSIT consultation	161	399
TEDI filtered view	337	527
PRORES / PREPLAB	59	147
Instruction validation	77	
Assume	563	
Shoot	449	

Questionnaire:

The possibility for the PC to negotiate with the aircraft by Data Link improves the control activity.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
			2	1	1

✍ Comment: *Has to be proved.*

10.4 Co-operation between controllers of adjacent sectors

(See Reference [1] - Internal topic 4: Assistance to co-operation between controllers of adjacent sectors).

The objective was to observe the co-operation between two adjacent control positions in an anticipated planning context. In the IOCP frame, no MSP has been simulated and inter-sector dialogues were not supported by the system, so the PD/3 concepts were present in a very limited way. Our major objective was to see whether providing ACI problems (which concerns the part of the trajectory after the aircraft has left the sector) enabled to alleviate co-ordination with the next receiving sector (thus enhancing anticipation).

General comment:

The co-operation part of the operational guidelines and the responsibilities sharing between positions were hard to understand by controllers. They found the procedure quite heavy and complex to apply at the beginning.

10.4.1 Co-operation strategy

Observations and interviews:

At the end of the experiment, the observed co-ordination strategy was closer to the operational guidelines:

- when the PC anticipated a non-equipped flight planning (to solve a problem or optimise) impacting entering conditions, he/she prepared the solution he/she mentally made with TEDI but without sending it. Then he/she co-ordinated with the giving sector either to delegate the change to the giving sector or he/she asked the giving sector to get the flight under his/her frequency to send it him/herself. Most of the time, he/she asked the contiguous sector to do it.

ERG SUGG: add a “ show proposed trajectory ” function between positions.

Co-ordination omission consequences:

They often forgot to co-ordinate when they used TEDI (at the beginning of the experiment above all).

We observed errors related to misunderstanding of planning authority:

- the PC forgot to co-ordinate and planned non equipped aircraft not under his/her responsibility which caused a non expected PRORES in the giving sector TC’s APD. This was source of confusion for the TC who did not understand the origin of the visualised PRORES which generated more communications and explanations.

ERG SUGG: a system support should be available to remind inter-sector co-ordination. For example, each time a co-ordination should be made, the system could visualise a “ co-ordinate ” message.

10.4.2 Co-operation and workload

Observations and interviews:

Controllers stated that anticipated planning created an additive workload as it caused more communications between sectors. Problems in ACI increased the information to take into account.

The PC tended to prepare long range clearances only when they were not too loaded because co-ordination was time demanding.

Co-ordination meant lots of micro-tasks to achieve: preparation by the PC, co-ordination with the contiguous PC who has to co-ordinated with his/her TC.

The experiment showed, when the PC was too loaded, he/she avoided to modify the part of the flight trajectory that was not in his/her sector, even if the solution was not optimal.

“ Co-ordination is going to be awful if we simulate all contiguous sectors ! ”

Questionnaire:

- problem representation at sector boundaries avoids starting co-ordination.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2	2				

✍ Comments: *On the contrary, it requires more co-ordination, that means more workload.*

10.4.3 Lack of common information shared between positions

Observations and interviews:

Controllers often complained about missing information whether or not the flight was already planned in the giving sector. This could induce re-planning for the same flight.

Controllers did not always visualise the same information from one position to another: one could visualise a conflict whereas one could not yet because the flight was not in a state that could be planned yet.

If the giving sector forgot to shoot a flight, the receiving sector could not modify anything until it was in his/her sector.

ERG SUGG: this information really have to be part of the inter-sector co-ordination.

10.4.4 Problem resolution in the ACI

Observations and interviews:

According to the controllers, PROSIT concerning conflicts in the ACI were useless: the controllers had tendency to destroy them as soon as they appeared. That kind of PROSIT overloaded the APD for problems controllers could not necessarily resolve.

Nevertheless, we observed that the controllers took these problems into account when, because of a problem occurring in their sector, they had to modify a trajectory of an a/c that was also involved in a problem in the ACI.

Quantitative data:

We calculated the number of PROSIT involving one same flight and appearing at the same time in the Agenda of the two sectors (problems in the ACI). We found that:

- in each exercise, the proportion of PROSIT involving one same flight and appearing at the same time in the Agenda of the two sectors was nearly the same,
- compared with the total number of PROSIT on the two sectors for all exercises, there were 21% of PROSIT involving at least one same flight.

Number of PROSIT involving at least one same flight appearing in the Agendas of the two sectors at the same time:

Exercise	N(PROSIT)	N(PROSIT) involving one same flight on the two sectors	Proportion N(PROSIT) involving one same flight/ N(PROSIT)
212	37	8	**22%**
213	63	13	**21%**
214	64	11	**17%**
215	72	15	**21%**
216	166	36	**22%**
217	70	14	**20%**
218	104	26	**25%**
TOTAL	**576**	**123**	**21%**

Questionnaire:

- The problem representation at sector boundaries allows the PC to anticipate resolution.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
				4	

✍ Comments: *But one must be sure that resolution will not create another conflict.*

- The problem representation at sector boundaries allows the TC to anticipate resolution.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
			1	3	

10.4.5 Planning transfer time to receiving position

Observations and interviews:

The implemented time for the experiment seemed to be adapted to controllers and simulated sectors .

They found it difficult to imagine the situation by mental anticipation:

"This concept completely breaks the actual mental scheme! It goes against all our conventions !".

10.5 Anticipated planning

(See Reference [1] - Internal topic 1: Assistance to plan and choose a solution).

Controllers (especially the PC) were requested to plan all flights as soon as possible, DataLink equipped or not.

10.5.1 Information available by the SIL (PC)

(See in Reference [1] - Internal Topic 1: Assistance to plan and choose a solution).

Observations and interviews:

The PC criticised the fact that not all information was directly accessible: *"There is too much hidden information! On this IOCP platform, there is much information on which we don't have direct access, when today we do!".*

The SIL did not display the flight destination: this information lacked to the controllers who have it permanently displayed today. The SIL lost its use without this information and had no further interest than the labels. The PC had to consult the label again to obtain flight plan information (contained on the extended label).

On the label, hyphen was sometimes displayed instead of waypoint. This bug prevented controller from a good flight integration and increased its workload. He/she had to consult again or ask for a filtered view (SIA) to point the cursor and display the waypoint.

When controllers integrated flights using the SIL, the filtered view overloaded the screen, because there was too much colour displayed.

SILs display could overlap some labels.

The PC seemed sufficiently warned when a new flight appears. He/she even used to anticipate flight appearance in the SIL by integrating flights that were not yet into account.

Flight integration by the PC

The PCs had tendency to consult SILs as soon as they appeared and to get rid of them as soon as possible to clean the radar display.

When a new flight appeared, the PCs opened the extended label and flight leg, and then the filtered view (SIA) to check any conflict. Information concerning the planned trajectory (i.e. the flight leg) seemed sufficient most of the time to execute anticipated planning.

Most frequently used tools to get information:

- **when the flight was conflict free**, the PCs used the TEDI for optimisation or placed an alarm clock to plan a flight level modification (Team 1) or do nothing. These actions trigger a plan mark display on the label.
- **when the flight was not conflict free,** the PCs used the TEDI filtered view (to see the red potential interaction areas). They eventually consulted the APD by opening extended PROSIT and using the extrapolation function from the PROSIT.

We did not observe integration of conflictual flights directly by the PROSIT.

Flight integration by the TC

With the proposed devices, before initial contact, the TC was not sure he/she had taken every flight into account.

The difficulty was due to the fact that the TC also had to integrate the flight mentally though he/she did not plan it. Now, **the TC did not have aids at his/her disposal that could allow him/her to make a systematic integration (SIL)**: SILs consultation would allow an upstream flight integration. He/She had no device to maintain flight information. This made TC’s work less efficient.

“I am not “ in ” the traffic! This role is too passive! I have almost nothing to do and I do not have a good image of traffic!”

This impossibility to integrate flights became uncomfortable, stressing and gave an insecure feeling especially at the beginning of the experiment.

CONTR SUGG: Some controllers proposed to manage SILs independently because both controllers need to integrate flights. Some other controllers proposed to visualise permanently an electronic stripping (like ERATO).

Questionnaire:

- **As a PC**, taking into account a flight in its context suits my personal work style.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	1			2	1

The look ahead function is a very useful tool.

- **As a PC**, the available information and aids are necessary and sufficient to perform anticipated planning.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	2		1	1	

✍ Comments:

- *anticipated planning sometimes causes other problems,*
- *insufficient flight integration and memorisation,*
- *difficulty to memorise conflicts.*

10.5.2 Heterogeneous flow planning

This topic deals with the influence of aircraft equipment on planning time, precision and success.

Observations and interviews:

<u>Differentiation between equipped and non equipped a/c by the controllers</u>

Depending on the label location, the datalink symbol was not always seen.

Moreover, we observed confusions (waiting for a PRORES for an equipped a/c or surprised to see a PRORES appear) related to not taking into account the a/c equipment (through not paying attention).

<u>Data Link interest</u>

We noted a strong DataLink benefit for controllers:

- it allowed to liberate the frequency for urgent messages,
- it relieved controllers from their mental workload: “The work is done with DL a/c whereas with the no DL a/c, you have to check if the TC actually sends the instruction by VHF ”.

<u>Management strategy</u>

The PC preferred to handle equipped a/c because they required less peculiar actions and demanded a lower workload (no need to supervise the TC for sending, ...). The PC had the feeling of a work “done ” when preparing equipped a/c trajectories. This was more comfortable for the PC.

Equipped and non equipped flight were generally processed the same way for conflict resolution.

On the other hand, controllers preferred making optimisation for DataLink equipped aircraft because it was easier to manage (no PREPLAB implies no communication between controllers and supervision for validation).

Exchange time had an influence:

- controllers planned equipped a/c early because of the time exchange constraint which represented an embarrassment for them,
- when the TC wanted to use the TEDI (in opposition to R/T instructions), we observed this tool was not adapted to real time (aberrant trajectories). See TEDI usability.

Questionnaire:

Handling a heterogeneous fleet made me to give priority to 4D FMS equipped aircraft.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2	2				

✍ Comments: *May be for optimisation but not for conflict resolution.*

10.5.3 Planning and co-ordination between sectors

(See Reference [1] - Internal topic 1 and 4: Co-operation between positions).

General comment:

The concepts of anticipated planning and planning authority between positions were hard to assimilate. The controllers seemed to be satisfied with the proposed working methods concerning the sharing of flight planning authority even if these instructions were difficult to apply at the beginning of the experiment.

Observations and interviews:

Advanced planning originated adverse effects: the sooner the flight was planned (e.g. optimisation outside the sector), the greater the risk to have to plan the flight again, which was contrary to the expected result: workload was increased.

Improvement in using anticipated planning by the PC at the end of the experiment, left us quite optimistic about this concept.

Improved training is expected to improve the results further.

Anticipated planning had a strong impact on co-ordination.

Trajectory modification became more flexible thanks to graphical tools, but this advantage also led to more co-ordinations to be optimal, trajectory had to be thought as a “between sectors ” trajectory. So, the PC had a more “ global trajectory’s ” view than a “sector’s ” view.

Controllers engaged less modifications outside the sector because of the co-ordination needed and the additional workload it implied (See chapter 4.3 Co-operation and workload).

<u>Workload due to co-ordination</u>

Controllers questioned anticipated planning efficiency when all sectors would be taken into account.

"Co-ordination load will be dreadful if we simulate all the adjacent sectors ! ".

Questionnaire:

- The possibility to plan the flight 10 minutes before its entry in the sector is efficient.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
				4	

✍ Comments: *But, negotiation with the other sector must not be too long.*

10.6 Operational quality of the experimented tools and aids

(See Reference [1] - Internal topic 5: Assessment of usability of assistance tools).

This section collects results dealing with HMI evaluation which is essential to tools and concept evaluation that HMI translates.

We specially focused on the assessment of utility and usability for the main tools and the following functions:

- TEDI,
- APD,
- filtered information,
- alarm clock,
- monitoring coding,
- system updating.

Some general aspects of the assessment of tools already have been discussed in the previous chapters (like mental load), but are detailed here.

10.6.1 TEDI (Trajectory editor)

In this part, we present the results related to the trajectory editor planning aid and problem resolution aid. This takes into account the trajectory modification up to the " send " instruction to board.

General tendencies:

Controllers stated that TEDI use had to be improved to be workable. At the beginning, they had a lot of difficulties, but they use it better and better.

TEDI suffered from many system limits and difficulties to use.

The direct " send " to board for equipped flights was very well accepted by controllers. As it could decrease load, they found it very useful and interesting.

We have pointed out the main problems linked to the use of TEDI.

Strategy of use:

Use of TEDI to solve a potential conflict

Once the PC chose the a/c to move, he/she used the extrapolation function (SIA) to see what could happen and visualised potential conflict areas. Then, after making a mental resolution, he/she used TEDI. Then, he/she systematically used the extrapolation function again to check if the problem was avoided.

We can not state if it was to check if the new trajectory was taken into account or if the conflict was actually solved.

Use of TEDI for flight optimisation

It seemed that non DataLink equipped flights were edited more seldom. They hardly ever tried to do so because the management of a PREPLAB was felt as an extra burden.

For DataLink equipped flights, the PCs opened the TEDI to give a direct route and SEND it to board. We observed that the PCs tended to check immediately if the new trajectory was taken into account by the system. But, as the system trajectory refreshing time was long, they visualised the previous trajectory and thought the system did not took into account their modification and they repeated their work.

The PC communicated with the TC (when not too loaded) to explain what he/she intended to do. We often observed the TC leant towards the PC's screen to see the trajectory he/she edited.

ERG SUGG: add a “ show proposed trajectory ” function between PC and TC of a same position.

Use of TEDI to visualise potential interaction areas

The PCs opened TEDI to check if conflicts detected by the system was a problem for them and, vice versa, if their conflict detection was a problem for the system.

Predominance of long range clearances

We observed that the manoeuvre starting point was often located before the sector and the resume point much further than the exit boundary.

Use of the editor by the TC

The operational guidelines stated that the editor was a PC tool in priority, but it seemed that the TC tried to use it more often than foreseen, especially when he/she had to integrate the flight and had nothing else to do.

Loss of flight identity

The offered tools facilitated the trajectory planning but also have a negative aspect: they manipulated a graphic object but lost the flight identification.

“ We lose the aircraft notion with the TEDI. It becomes a level, a graphic object but without any proper identity! ”

Utility:

Conflict resolution aid

Controllers felt that TEDI was not very useful without a dynamic visualisation of potential conflicts when editing a new trajectory.

Restricted use of datalink

Controllers found frustrating to issue immediate R/T clearances whereas strategic clearances could be transmitted by datalink (especially level clearances).

The four controllers stated that datalink was a great concept they would like to see available for all a/c.

Usability:

We observed numerous attempts to edit and send a trajectory which produced irritation and sometimes renouncing (use of other means).

Too long response time

TEDI response time (trajectory refreshment) was felt not compatible with control constraints.

As response time was sometimes too long, controllers tended to send heading instruction by VHF even for datalink flights, this way, they were sure the instruction was received.

Difficult trajectory manipulation

The too small active area on the trajectory induced difficulties to edit a new trajectory. Mouse pointing was very difficult. It sometimes led to bad selection caused by overlapping.

Unintentionally, controllers often selected what was under the trajectory (menu, assume...) without always realising it.

Complexity to use

The way to edit a trajectory with logic turning points was not always perceived as intuitive especially to edit direct routes. They stated VHF was faster.

TEDI did not allow to make up for a mistake on a turning point. They were obliged to start all over again.

The given heading information was not always precise enough for controllers. The degree information used when giving a heading to edit a trajectory should be more precise.

ERG SUGG:

- *provide a function that allows to modify a point by moving the clearance marker on the trajectory (like moving a constraint in PD3), instead of re-editing a new trajectory,*

- *prefer a direct menu to change heading,*

- *provide an elastic vector while moving heading.*

Parallel use of TEDI

The parallel use of TEDI between PC/TC or with the adjacent sector caused system problems that made it impossible to use (without being aware that someone else is using it).

Very short ahead time and 360° trajectories

Not being able to start a manoeuvre earlier than 2'30 ahead of current flight position was felt as a trouble to controllers, especially when they wanted to give optimal direct routes.

“ We should create the first point from the current position of the aircraft! ”

In many cases, it seemed that “active anticipation” was not really put into practise (not only analysis but resolution).

This inactive area changed during experiment (time tested: 1', 2'30'', 1'30'').

Too short time ahead led to unexpected trajectories: as the time to send a trajectory was very long, the first turning point was passed!

This underlines **the importance of the moment to give the possibility to modify the trajectory**.

ERG SUGG: whatever this time could be controllers always have to know which part they can act on, for example: flip-flop coding on the trajectory.

Questionnaire:

- TEDI management functions (SIA filtered view, planning aid, conflict areas visualisation) are useful and easy to carry out.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	1	1	1	1	

✍ Comments: *TEDI management is much too heavy.*

10.6.2 APD

General comment:

The APD overloaded the screen. According to the controllers, the APD should be placed on another screen, but this opinion must be handled with care, as it is partly due to the major role given to the Plan View Display in today context.

It seemed controllers were not enough trained to the new working methods to use the APD as they should have.

10.6.2.1 PROSIT

Observations and interviews:

<u>PROSIT use strategy</u>

PROSIT was used more as a conflict "aide memoire" function than as a conflict detection aid. Controllers seemed to have a limited confidence in the system and went on detecting conflicts when they had the means to do.

Controllers systematically displayed extended PROSIT when they were in the middle of the APD (not as soon as they appeared). PROSIT extended function, displaying the list of callsigns of the aircraft involved in the problem was always used because it gave the needed information.

CONTR SUGG: display the extended PROSIT as soon as it appears with possibility to close when consulted.

The PCs pointed the cursor on every PROSIT involved flight to make themselves acquainted (it was easier that way to locate the a/c individually). The PCs used the highlighting facility associated with passing the cursor on the PROSIT: given the great number of already existing codings, this attracted their attention better than a "fixed" coding .

The PCs consulted the extrapolation function from the PROSIT. This was really helpful to decide on which flight to act. The extrapolation function was easy to use with the PROSIT and very appreciated by controllers.

<u>PROSIT information collection</u>

The APD was often used to make up for delay on conflict detection after an overloaded period (often due to the use of the trajectory editor). Controllers proceeded in two steps:

- a grouped consultation of conflict labels when they have time enough ;
- a "cleaning" of the APD.

PROSIT removal

Controllers tended to remove PROSIT as soon as possible, when:

- problems did not belong to the sector (ACI problem...) (See Theme 4);
- there was no problem according to them;
- the problem was completely solved (according to the PC) (See Theme 2).
- the controllers preferred to trust the extrapolation function rather than the potential conflict detection aid (red areas). Effectively, the extrapolation function suited the mental image the controllers made on the a/c better: it was a more adapted support to take decisions and a more useful aid.

Lack of reliability in conflict detection

Potential conflict detection of the system was not exactly the same as controllers own mental detection: **the system tended to over or under estimate conflicts which caused a lack of confidence in the system**.

For example, this lack of reliability could be explained by the fact the system did not calculate conflicts if the trajectory was not updated early enough.

Controllers criticised some PROSIT occurrence or lack of relevance (system pessimism, ACI problem).

Controllers criticised the relevance of PROSIT time display.

"A new PROSIT is not always easy to notice".

Traffic fragmented view

"Not to detect conflicts on our own makes we don't have any global view of traffic. We just have a fragmented view!".

If the PC concentrated too much on the APD, he/she lost traffic notion. This was also caused by the general working method guidelines, which prompted the controller to integrate the traffic through the APD. This guideline has to be amended, as explained in section 3.4 "Working method guidelines".

This tool was useful, but the PC was not confident enough to completely rely on it. He/She wanted to keep his/her own traffic image.

Problem in the ACI

(results already mentioned in 10.4.4)

PROSIT wording

It happened to see the PROSIT wording truncated when too long (for example, the end of the destination name).

The conflict symbology was complex: their interpretation was sometimes rather hard.

PROSIT wording was not detailed enough.

Wording was complex: sometimes it took more time to understand rather than detecting conflicts on the radar display. Controllers preferred to detect problems directly on the radar display as today.

Usability

We observed, especially with Team 1, difficulties to assimilate and perform different suppression possibilities of PROSIT (drag to the dustbin, right button, left button to answer the system suppression proposal): there were too many possible procedures and different coding.

There was too much information presented in the extended PROSIT: according to one of the controllers, it would be sufficient to present destination, flight type and RFL.

We observed bad manipulation when using the extrapolation function, the controllers sometimes moved by mistake the PROSIT by releasing the cursor in the APD.

10.6.2.2 PRORES/PREPLAB

There was an evolution during the simulation: at the beginning, a PRORES/PREPLAB could be validated both by TC and PC. Later on, only the TC could validate it.

Observations and interviews:

PRORES/PREPLAB creation and strategy of use

For the PC, creating a PRORES or a PREPLAB meant warning and supervising the TC not to forget to give instructions to the pilot (See Theme 2).

For the TC, PRORES or PREPLAB presence meant search of information concerning the PC's resolution or optimisation (communication between PC/TC).

Even when they did not agree about the solution, the TC rarely refused.

Consequences:

As creating a PRORES/PREPLAB caused additional workload, the PC hesitated to make optimisation for a non equipped aircraft because it caused PRORES/PREPLAB and more workload (due to communication, explanation, understanding).

The TC felt passive.

Utility

System implies a passive role for the TC that he/she was not ready yet to accept because he/she wanted to have a critical look on the work already done.

HMI implemented functions on this prototype did not enable a sufficient information sharing between the two controllers.

Usability

PRORES/PREPLAB acquittal was frequently forgotten especially when radar display was overloaded.

Symbols were not very explicit. Ex: the direct symbol (an arrow) was not very clear.

ERG SUGG: prefer a D symbol for a direct rather than an arrow (same for the H - heading- symbol).

It was difficult to respect the right moment to send instructions to the pilot (workload problem and/or PRORES/PREPLAB not seen). If the instruction was not sent at the right moment, then the controller could not do anything and filtered views were not valid anymore. The controller had to plan the flight again.

At the beginning, controllers hardly took into account the arrow indicating the PRORES/PREPLAB contained other instructions.

Problems of information sharing were observed concerning trajectory modification elaborated by the PC, when the TC did not know or remember the previous one.

Questionnaire:

- The set of APD's management functions (change of scale, change of time interval, addition/refusal of a new a/c in a problem...) is useful and easy to carry out.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	1	1	2		

✍ Comments:

- *the extrapolation function would be sufficient,*

- *it lacks a dynamic conflicts visualisation.*

10.6.3 Filtered views

General comment:

According to controllers, filtered views generated a partial perception of traffic because of filtering focusing. Conflict memorisation seemed to be difficult.

Filtered views were not always perceived as an aid because they gave a feeling of insecurity. The question of conflict detection efficiency came up.

Controllers felt that filtering functions were unworkable:

- too many different access to the filtered views (Callsign + XPT). "That's too much".

- too much different colours which made it difficult to memorise and understand the coding,

- much advanced information.

They often preferred to make their own filtered view through their own analysis.

10.6.3.1 SIA

Use strategy

The SIA filtered view was the most used because it was the simplest to understand (this filtered view did not contain too much coding).

Controllers used to open this filtered view to check if the system took well into account trajectory modification and if potential conflicts disappeared (which should be useless for trajectory modification should be dynamically displayed at the time the controllers use).

The place, where the a/c would probably be, was visualised with the help of the extrapolation function..

The SIA filtered view was also used to choose a flight for conflict resolution.

10.6.3.2 The TEDI filtered view

General comment:

Doubts about failures and system reliability caused checking through the TEDI filtered view and hence, additional workload.

The TEDI filtered view was not significant. Controllers found it unworkable and then, they did not use it.

Visualisation of red areas overloaded the screen and stressed controllers, because they appeared too large.

Concerning colours, the green of interfering a/c set off too much (a green too bright).

"It's a real Christmas Tree ! You don't see anything!".

According to the controllers, the TEDI filtered view appeared to be too complex to work with.

We observed this complexity generated confusion, incomprehension. difficulty to memorise coding, an bad traffic memorisation. We noticed controllers lost a lot of time trying to understand coding (interpretation was difficult).

The filtered view analysis was responsible for demanded workload.

Utility

Controllers found that the TEDI filtered view and conflict/interaction area sometimes appeared **non relevant** (too pessimistic or too optimistic), and created more workload. They could not rely on this function because of its lack of relevance (See Theme 3) and did not really use it.

Interaction areas visualisation lost its interest for controllers since these areas were not simultaneously refreshed with trajectory modification (dynamism).

Controllers felt that level filtered views were missing.

10.6.3.3 STU filtered view

(See reference [1] - Internal topic 1: Assistance to plan and choose solution).

General comment:

Controllers had difficulties with this tool because codings were to complex and there was a lack of relevance of interaction red segments.

Observations and interviews:

<u>Filtered view utility</u>

(See in Reference [1] - Internal Topic 1).

Critics related to filtered views were as much linked to the concept as to the implementation defaults (colour coding to be revised, interaction areas detection reliability to improve...).

Nevertheless, filtered views allowed to use the extrapolation function (especially by the means of PROSIT labels in the APD) which was quite straightforward and could help to take a decision.

10.6.4 Alarm clock

Observations and interviews:

Strategy of use

The alarm clock was used to compensate the lack of vertical editor window (which would allow anticipated level planning).

In low loaded situations the alarm clock was sometimes used by the PC, to warn the TC of a level change.

The TC sometimes used it for the same reason, generally in the same condition of low traffic.

Usability

The transfer logic being different from the PROSIT one, the PC often forgot to transfer the alarm clock manually.

ERG SUGG:

- *allow an automatic transfer to be homogeneous with the PROSIT,*

- *according to controllers, the alarm clock colour was too bright.*

10.6.5 Coding related to surveillance

(See Reference [1] - Internal topic 3: Assistance to memorisation and monitoring).

Observations and interviews:

The set of coding presented simultaneously and their informational content tended to reduce their relative attention mostly concerning the filtered views. The coding appeared not very useful.

Alarms (related to PRORES, PREPLAB or PROSIT exceeding the limit time) did not seem to be always relevant, because controllers did not take them into account. These alarms were the following ones:

- the planning mark becoming flashing red at the same time as a PRORES/ PREPLAB alarm,
- the labels becoming yellow on the radar display (meaning that a PRORES/ PREPLAB or a PROSIT was in limit time),
- the PRORES/PREPLAB, PROSIT or alarm clock in yellow in the APD.

The fact that controllers did not take into account these alarms was due either to forgetting, or to controllers own judgement not to be interested in them.

Questionnaire:

- The set of coding is helpful for supervising traffic.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	1	1		2	

✍ Comments:

- *lack of coding which indicates the flight has not been seen yet by TC*

- *problem of coding complexity: loss of concentration.*

10.7 System updating

(See Reference [1] - Internal topic 3: Assistance to memorisation and monitoring).

General comment:

Whereas system updating was not very easy to apply (especially with label menus), they understood its interest well. Nevertheless, we observed many cases of validation omission.

Observations, interviews:

Label menus and PRORES/PREPLAB validation by TC

At the beginning, TCs tended to take system updating for a send to pilot. They were sure the instructions were sent whereas they only updated the system.

System updating became more and more systematic when they often forgot during the first simulations. It was always consecutive to the use of VHF.

We observed that non system updating was often related to overload. But this was not the only reason, PRORES/PREPLAB non validation was very frequent for the following:

- they knew they were not of interest anymore,
- they did not concern them (because of a co-ordination error with the adjacent sector),
- they did not pay a lot attention to the APD and were more focused on the radar display.

We noticed many unintentional value entries in menus because they released the mouse at a wrong value. Controllers could not use menus to know the current value because when they open the menu, the visualised value was a random value. For example, it was impossible to visualise speed in Mach points whereas it was in Knots.

The interaction mode for system updating was not very workable and discouraged controllers who soon abandoned: the entry did not work at the first time. Controllers had to do it several times. Menus were not very adapted to enter headings.

CONTR SUGG: prefer menu with an elastic vector, easier and more relevant.

TST (TEDI) menu

TST menu appeared sometimes at the limit of the screen corner which did not permit to clic in it without moving the radar display.

The “SEND ” or “RESET ” enter was difficult because of the selection zone compared to the cursor which was too big.

Mouse actions (assume, shoot)

Most of the time, the TC updated the system after calling the flight. But when traffic was higher we noticed the TC asked the PC to update.

Double clic was constraining, not easy to succeed at the first try. These actions were not always taken into account by the system and the TC did not always notice.

Questionnaire:

- Informing the system (data entry) gave me useful information for memorisation and supervising.

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
		1	2	1	

✍ Comments: *Problem of label information memorisation.*

11. Appendix B: Traffic samples preparation

11.1 Data preparation

Data preparation consists mainly in the elaboration of:

- **flight plans** which constitute traffic samples
- data related to **simulated airspace**

11.1.1 Flight plans

Flight plans have been extracted from the PREVI database dated 26th of June 1996. This day has been selected because of its significant number of movements.

11.1.2 Simulated Airspace

Simulated airspace was composed of UN/XN and UR/UY En Route sectors from CRNA Reims (measured sectors) and their adjacent sectors.

A preliminary study, based on sector manuals from CRNA Reims and CRNA Paris, allowed to analyse the sectors specificity and to develop the algorithms necessary for the management of LOAs in the DAARWIN system.

11.2 Construction of traffic samples

Test samples have been first elaborated for technical tests at HMI level.

11.2.1 Database formatting

First , 928 flight plans were extracted from the PREVI database and put in EXCEL format.

Then, using EXCEL facilities, each flight plan was enhanced with additional data required for the simulation. Each flight was provided with a flow number.

11.2.2 Traffic sample

Traffic samples were generated by extraction of a sub-set of flight plans from the EXCEL database. Extraction is made according to a selected time slot.

The choice of the time slot depends on the nature, interest and density of the traffic flows required for the experiment. The number of extracted flights has to correspond, after adjustments, to an hourly load which is not beyond the capacity of the two measured sectors. According to the protocol of experiment, it has not been planned to let this hourly load change. For the IOCP and taking account of its exploratory character, it has not been agreed to limit the duration of each sample to one hour.

12. Appendix C: Table of measured exercises affected by technical deficiencies

Training runs	System malfunction was not considered as very penalising during the runs, because controllers were not supposed to "control" but to get used to HMI and functions in a realistic context. DL communications breakdowns were quite frequent and caused a loss of time. Due to the restart of some runs from the beginning, it is assessed that only 8 hours of simulated traffic was actually played (instead of the 10 hours available). However the global active simulation time for each controller is assumed to be 10 hours.
No 212 (21.04,Mor.)	3 HMI breakdowns on UR/UY 3 HMI breakdowns on UR/UY Controllers and pseudo pilots not yet used to some of the system limitations, which caused a lot of questioning and loss of time. Some cases of late (or lost) trajectory updates.
No 213 (21.04,After.)	1 HMI breakdowns on UR/UY 2 HMI breakdowns on UN/XN Some cases of "unexpected guidance"
No 214 (22.04,Mor.)	1 HMI breakdowns on UR/UY 1 HMI breakdowns on UN/XN No major malfunction
No 215 (22.04,After.)	1 HMI breakdowns on UR/UY No major malfunction
No 216 (23.04, Mor.)	5 HMI breakdowns on UR/UY 1 HMI breakdowns on UN/XN A very penalising case of "random stack" at T0+30[7].
No 217 (24.04, Mor.)	1 HMI breakdowns on UR/UY DL communications breakdown at T0 + 20, causing complete re-start.
No 217 (24.04, Mor.)	HMI breakdowns not recorded The second run was satisfactory (except that the first 20 minutes of traffic were already known).

[7] **Unexpected traffic generator guidance behaviour** (due to a design mistake in the trajectory editor): the trajectory editor enabled the controllers to input turning points very close one to another. The guidance function of the traffic generator then tried to start a circular manoeuvre to try and capture the neighbouring point.

No 218	*1 HMI breakdowns on UR/UY*
(25.04,Mor.)	*1 HMI breakdowns on UN/XN*

13. Appendix D: Working methods guidelines

Here after is provided the script (in French) of the operational guidelines given to controllers. A translation into English is given further on.

Les consignes opérationnelles en trois points

(1) ***Le partage des tâches:***

- *le PlanningC choisit les vols sur lesquels il est judicieux d'agir assez tôt et les planifie(résolution ou optimisation)*
- *le TC se charge des actions laissées en attente par le PlanningC et surveille ou réalise les actions prévues*

(2) **Les coordinations inter-secteur: ne pas les alourdir à cause de l'anticipation**

(3) ***Le traitement du trafic mixte: ne pas pénaliser les avions "DL"***

Partage des tâches

Consignes concernant la responsabilité:

?***Consignes****:*

Vol planifiable = le PlanningC a la **responsabilité de planification** *jusqu'à ce que le vol soit "arrivé" sur le secteur*

Vol arrivé = le premier contact radio a eu lieu + le TC a assumé le vol

Vol assumé = le TC a la **responsabilité de contrôle**

?***Rappels*** *concernant les outils de l'interface:*

Les deux ***états de vol*** *principaux:*

- Vol planifiable: ***ENCADRé ROUGE***

- Vol assumé: ***BLANC***

Consignes concernant l'intégration du vol:

?***Consignes****:*

- ***Prise en compte du vol par le PlanningC***

Attendre l'état planifiable puis:

SIL → PROSIT → TEDI

- ***Prise en compte du vol par le TC***

Un vol est pris en compte par le TC après la planification effectuée par le PlanningC

N'assumer le vol qu'après le contact initial fait par le pseudo pilote

PROSIT *et/ou* ***PRORES → action tactique VHF*** *et renseignement des menus (ou TEDI)*

?***Rappel*** *concernant les outils de l'interface:*

soit le PlanningC a agi sur la trajectoire du vol: présence du "g"

soit il l'a considérée comme OK et n'y a rien fait

soit il l'a considérée comme "à surveiller" et l'a signalé à son TC (PROSIT toujours présente)

Consignes concernant l'envoi de clairances:

?***Consignes****:*

C'est le ***PlanningC*** *qui utilise l'éditeur en priorité*

La gestion des ***PRORES*** *est de la responsabilité du* ***TC****.*

- Les menus ***CFL****, C,V,T sont réservés au TC (sauf "délégation" d'une saisie au PlanningC), les saisies doivent être faites en même temps que la clairance VHF* ***que les vols soient équipés ou non.***

Seul le menu TFL est utilisé par le PlanningC, pour ***prévoir*** *le niveau de sortie, le renseignement de ce menu TFL ne s'accompagne pas d'une action de contrôle, son but est de permettre au PlanningC de donner une indication au TC.*

?***Rappels*** *concernant les outils de l'interface:*

L'éditeur de trajectoire horizontal:

pour les avions DL: *l'éditeur permet de* ***renseigner*** *le système et d'envoyer une clairance dite "stratégique".*

pour les avions NON DL: *l'éditeur permet de* ***renseigner*** *le système UNIQUEMENT et de générer une* ***PRORES*** *qui aidera à transmettre les ordres de contrôle correspondant au bon moment.*

Les ***menus*** *(CFL, TFL, C,V,T) ne servent qu'à* ***renseigner*** *le système.*

Le menu ***TFL*** *est celui qui se trouve à côté de la balise de sortie (ligne 3 de l'étiquette).*

La saisie d'un TFL peut s'accompagner de la saisie d'un "marqueur" sur la trajectoire.

Les actions immédiates (dites "tactiques") sont faites exactement de la même façon pour tous les types de vols (équipés DL ou non).

Coordinations inter-secteur

?***Consignes:***

Le PlanningC doit planifier les vols le plus tôt possible dés qu'ils passent à l'état planifiable *(pour le flux UR/UY>UN/XN, si le vol n'est pas impliqué dans un problème qui doit être réglé par le TC, le but, pour UR/UY est de le planifier le vol avant que le PlanningC de UN/XN ne le connaisse).*

Le PlanningC doit planifier les vols le plus tôt possible dés qu'ils passent à l'état planifiable, s'il le fait plus tard, ***il doit se coordonner avec le secteur recevant.***

Si le PlanningC doit modifier les conditions d'entrée du vol, ***il doit se coordonner avec le secteur donnant:***

- soit il délègue l'action au secteur donnant,

- soit il demande le vol en fréquence plus tôt pour faire lui-même l'action.

Une modification de trajectoire ne peut être faite que si le secteur où se trouve la première partie de la trajectoire concernée par la modification a l'avion en fréquence[8].

? ***Rappel concernant la configuration de l'espace entre UR/UY et UN/XN:***

Lors de sa prise en compte par le PlanningC, le vol est à 10mn de l'entrée du secteur.

Lors de la prise en compte d'un vol par le PlanningC, le vol est à peine arrivé dans le secteur précédent.

Sur les flux traversant UR/UY et UN/XN, les vols sont **planifiables** *pour UN/XN*

~5mn avant l'entrée dans UR/UY.

Lors de la prise en compte d'un vol par le PlanningC, les conditions de sortie du secteur donnant ont normalement été considérées par le PlanningC précédent, on doit donc considérer en priorité l'aval de son secteur (sur les flux traversant UR/UY et UN/XN, le PlanningC de UR/UY doit pouvoir considérer la situation dans l'ACI (axe MTD/MONUR)).

[8] Cette consigne n'était pas suffisamment claire exprimée ainsi. Il aurait fallu la compléter: "*Une modification de trajectoire ne peut être faite que si le secteur où se trouve la première partie de la trajectoire concernée par la modification a l'avion en fréquence,* ***c'est ce secteur qui devra faire la modification de trajectoire en priorité***"

Operational guidelines

Hereafter is a rough translation of the operational guidelines. It is meant to be shorter, as mentioned in the recommendation part of the conclusion.

Task sharing

- **The planning Controller must be decisive:**

  ∗ has to chose which flight to act on .

  ∗ may choose to leave "pending problems" to the TC (if he/she is not sure he/she is the one who will settle the problem the most efficiently).

  ∗ must think of optimisation as often as possible.

- **The tactical controller must be "executive" !**

  he/she must be "on the ball" and keep him/herself in the picture for quick reactions.

- **Task sharing in more detail**

  ∗ **Responsibility:**

  1? The PC should take the flight into account.

  2? The PC should plan the flight.

  3? The PC should consider it as being on the way and monitor it on its way.

  1? The TC should take into account the flight and the preparatory work already done by the PC before first contact.

  2? The TC should assume the flight at the first contact.

  3? The TC should take responsibility for the flight.

  ∗ **Communication with aircraft.**

  ∗ The right tool for the PC is the Trajectory Editor, because he/she is dealing with long term actions.

  ∗ The right tool for the TC is the R/T.

  ∗ **System update.**

  ∗ Actions initiated trough the Trajectory Editor are automatically fed into the system.

  ∗ Short notice clearances given through R/T MUST ALSO be input into the system.

Inter-sector co-ordinations

- **The PC must plan each flight as early as possible** (and as early as the system allows to plan it: planning authority).
- **If the PC fails to plan in advance, he/she must notify the next receiving sector of subsequent changes that impact this next sector.**
- **If PC of sector N wants to make changes that impact N-1 exit conditions, he/she must notify TC N-1, and, preferably delegate the change to him/her.**

14. Appendix E: Detailed Time table (training + runs)

TRAINING WEEK 16th		
	MORNING	**AFTERNOON**
MONDAY 14th APRIL	**10h00-12h00: Concepts presentation**	**Glimpse on the proposed sectorization** Planning and questionnaires presentation
TUESDAY 15th APRIL	**HMI main principles presentation:** Co-operatives Tools: APD, PROSIT and PRORES, trajectory editor , traffic filtered views, etc.	**Exercise 219**: **Macro functions study** Sequence A: Flight states and SIL Sequence B: The label (label management and radar display) Sequence C: Differentiation between equipped/non equipped flight New flight integration without conflict **Debriefing** **Operational instructions presentation**
WEDNESDAY 16th APRIL	Directed mini-exercise **Exercise 220** Sequence A**:** New non equipped flight integration creating a problem Pseudo-pilot attendance	Directed mini-exercise **Exercise 221** Sequence A: New equipped flight integration creating a problem with two flights in the simulated sector Sequence B: New equipped flight integration creating a problem in the ACI Sequence C: Study of different cases of flight level modification Two pseudo-pilots attendance

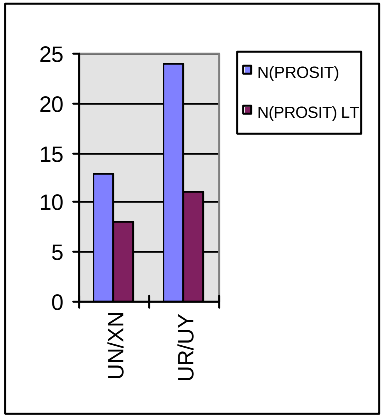
THURSDAY 17th APRIL	Training exercises **Exercise 222** A one hour sample: 20 aircraft an hour A 20 minutes break A one hour sample: 30 aircraft an hour Two pseudo-pilots attendance (9h00-11h00)	Training exercises **Exercise 223** A one hour sample: 40 aircraft an hour A 20 minutes break A one hour sample: 45 aircraft an hour Two pseudo-pilots attendance (14h15-16h10) Training questionnaire
SIMULATION PHASE BEGINNING		
FRIDAY 18th APRIL	**N° 211**: Aix plays UR/UY - Bordeaux plays UN/XN Two pseudo-pilots attendance (9h00-11h00) Debriefing + Interview	**N° 211**: Aix plays UN/XN - Bordeaux plays UR/UY Two pseudo-pilots attendance (14h15-16h10) TLX Debriefing + Interview
SIMULATIONS WEEK 17th		
MONDAY 21st APRIL	**N° 212**: Aix plays UR/UY - Bordeaux plays UN/XN Two pseudo-pilots attendance (9h00-11h00) Debriefing + Interview	**N° 213**: Aix plays UR/UY - Bordeaux plays UN/XN Two pseudo-pilots attendance (14h15-16h10) TLX Debriefing + Interview
TUESDAY 22nd APRIL	**N° 214:** Aix plays UR/UY - Bordeaux plays UN/XN	**N° 215**: Aix plays UN/XN - Bordeaux plays UR/UY

	Two pseudo-pilots attendance (9h00-11h00) Debriefing + Interview	Two pseudo-pilots attendance (14h15-16h10) TLX Debriefing + Interview
WEDNESDAY 23rd APRIL	**N° 216:** Aix plays UN/XN - Bordeaux plays UR/UY Two pseudo-pilots attendance (9h00-11h00) Debriefing + Interview	**First results analysis**
THURSDAY 24th APRIL	**N° 217:** Aix plays UN/XN - Bordeaux plays UR/UY Two pseudo-pilots attendance (9h00-11h00) Debriefing + Interview FINAL QUESTIONNAIRE + Results analysis	GENERAL EVALUATION **PHARE** PROSPECT PRESENTATION AND OPENED DISCUSSION ON ASKED QUESTIONS
FRIDAY 25th APRIL	**Exercise N° 218**: **PD3 loaded simulation** Choice of sectors Controllers point of view collection No foresaw script, quantitative measures are pursued. Debriefing.	

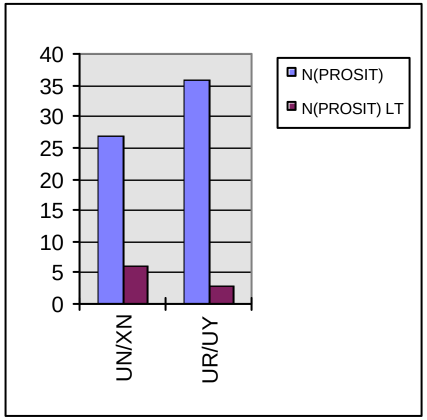
15. Appendix F: Table of quantitative data

NUMBER OF PROSIT/ NUMBER OF PROSIT ARRIVED IN LIMIT TIME

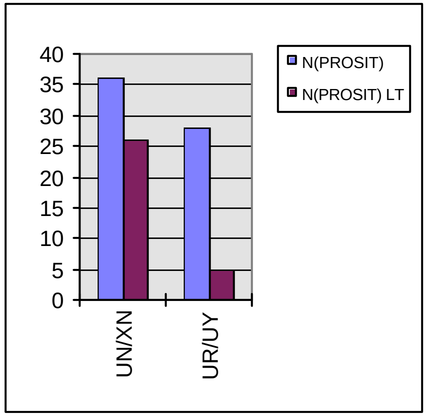
Exo 212	UN/XN	UR/UY
N(PROSIT)	13	24
N(PROSIT) LT	8	11



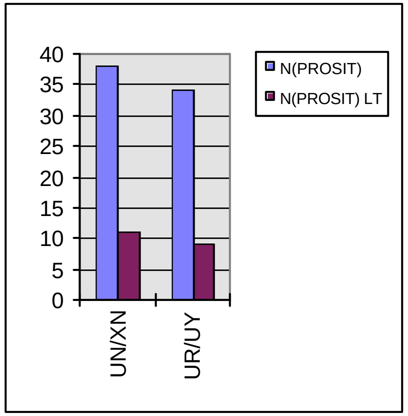
Exo 213	UN/XN	UR/UY
N(PROSIT)	27	36
N(PROSIT) LT	6	3



Exo 214	UN/XN	UR/UY
N(PROSIT)	36	28
N(PROSIT) LT	26	5



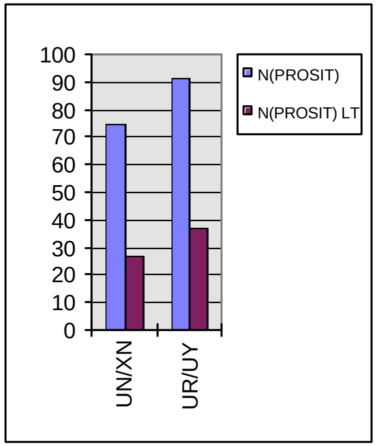
Exo 215	UN/XN	UR/UY
N(PROSIT)	38	34
N(PROSIT) LT	11	9

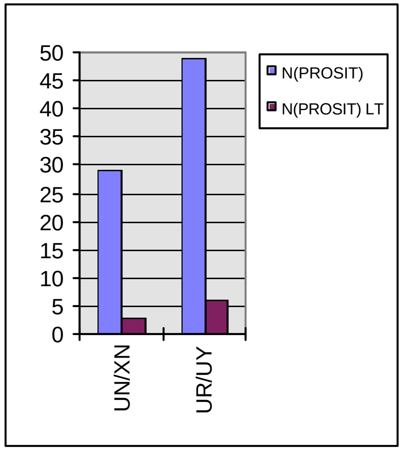


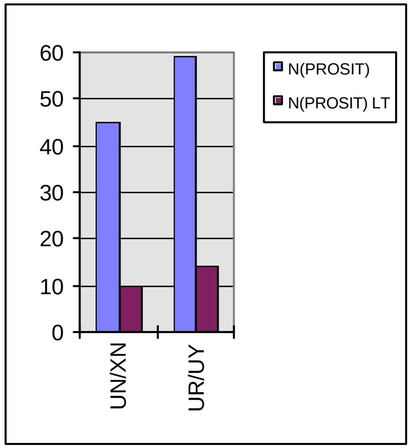
Exo 216	UN/XN	UR/UY
N(PROSIT)	75	91
N(PROSIT) LT	27	37

Exo 217	UN/XN	UR/UY
N(PROSIT)	29	49
N(PROSIT) LT	3	6

Exo 218	UN/XN	UR/UY
N(PROSIT)	45	59
N(PROSIT) LT	10	14

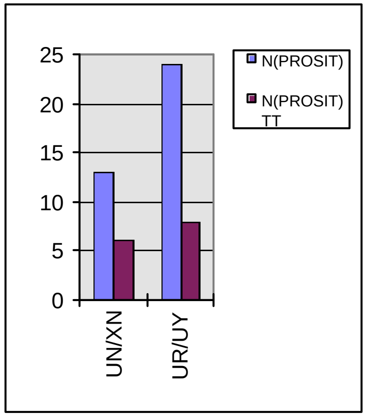




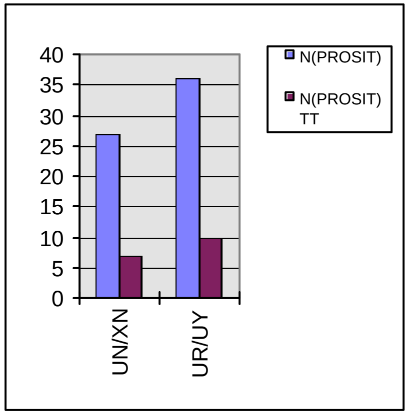


NUMBER OF PROSIT TRANSFERRED TO THE TC BEFORE THE PC MADE AN ACTION ON THEM

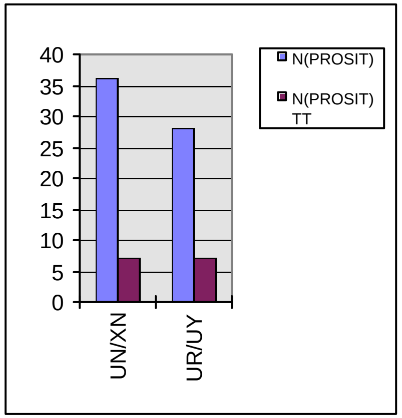
Exo 212	UN/XN	UR/UY
N(PROSIT)	13	24
N(PROSIT) TT	6	8



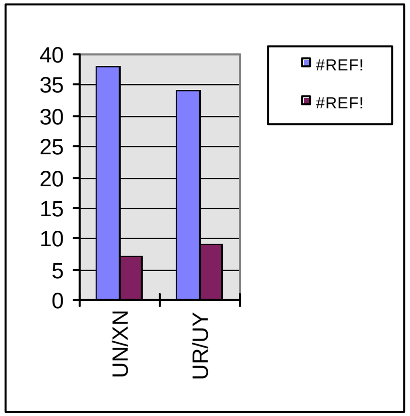
Exo 213	UN/XN	UR/UY
N(PROSIT)	27	36
N(PROSIT) TT	7	10



Exo 214	UN/XN	UR/UY
N(PROSIT)	36	28
N(PROSIT) TT	7	7



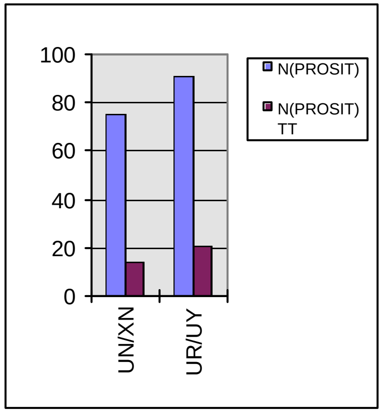
Exo 215	UN/XN	UR/UY
N(PROSIT)	38	34
N(PROSIT) TT	7	9

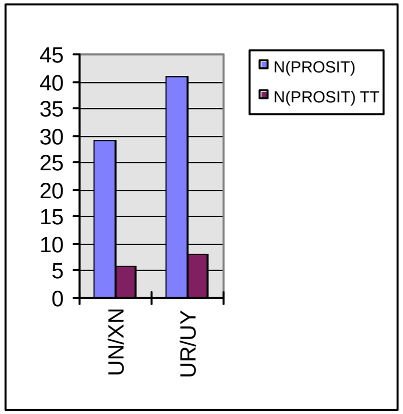


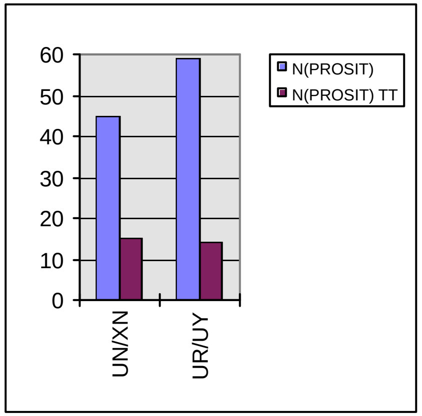
Exo 216	UN/XN	UR/UY
N(PROSIT)	75	91
N(PROSIT) TT	14	21

Exo 217	UN/XN	UR/UY
N(PROSIT)	29	41
N(PROSIT) TT	6	8

Exo 218	UN/XN	UR/UY
N(PROSIT)	45	59
N(PROSIT) TT	15	14

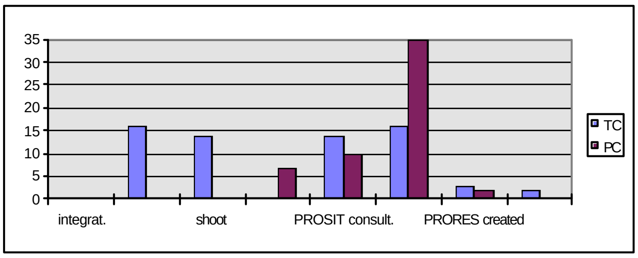




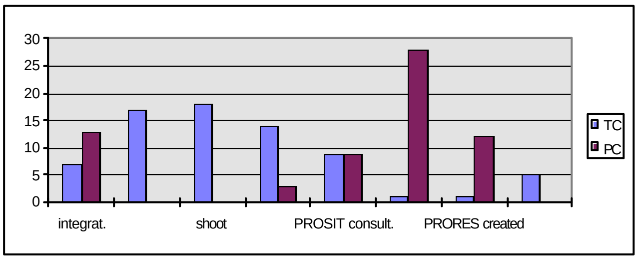


NUMBER OF FUNCTIONS CARRIED OUT IN EACH EXERCISE BY EACH CONTROLLER ON EACH SECTOR

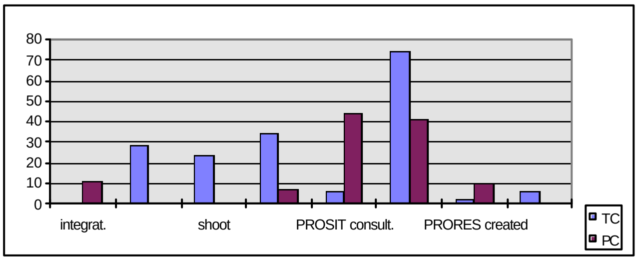
Exo 212	UN / XN	
Fonctions	TC	PC
integrat.	0	0
assume	16	
shoot	14	
extended label	0	7
PROSIT consult.	14	10
TEDI filtered view	16	35
PRORES created	3	2
Instruct. validated	2	
TOTAL	65	54



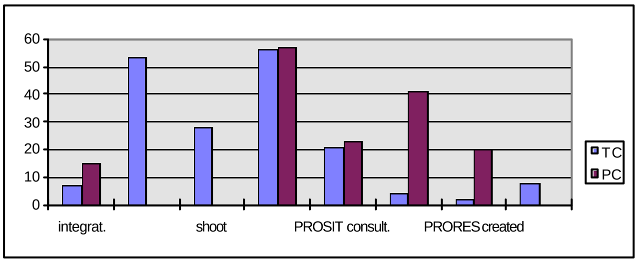
Exo 212	UR / UY	
Fonctions	TC	PC
integrat.	7	13
assume	17	
shoot	18	
extended label	14	3
PROSIT consult.	9	9
TEDI filtered view	1	28
PRORES created	1	12
Instruct. validated	5	
TOTAL	72	65



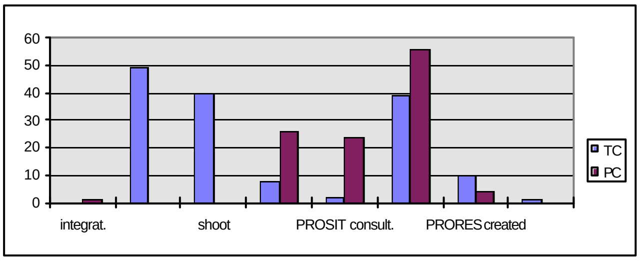
Exo 213	UN / XN	
Fonctions	TC	PC
integrat.	0	11
assume	28	
shoot	23	
extended label	34	7
PROSIT consult.	6	44
TEDI filtered view	74	41
PRORES created	2	10
Instruct. validated	6	
TOTAL	173	113



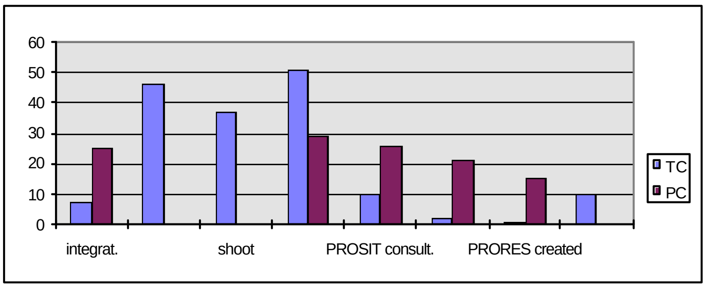
Exo 213	UR / UY	
Fonctions	TC	PC
integrat.	7	15
assume	53	
shoot	28	
extended label	56	57
PROSIT consult.	21	23
TEDI filtered view	4	41
PRORES created	2	20
Instruct. validated	8	
TOTAL	179	156



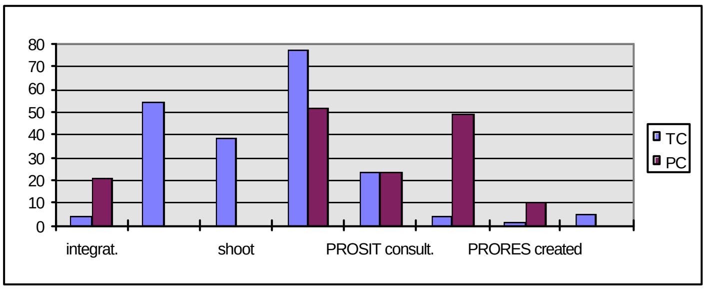
Exo 214	UN / XN	
Fonctions	TC	PC
integrat.	0	1
assume	49	
shoot	40	
extended label	8	26
PROSIT consult.	2	24
TEDI filtered view	39	56
PRORES created	10	4
Instruct. validated	1	
TOTAL	149	111



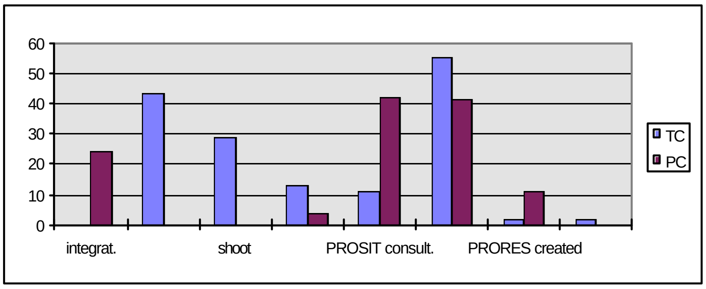
Exo 214	UR / UY	
Fonctions	TC	PC
integrat.	7	25
assume	46	
shoot	37	
extended label	51	29
PROSIT consult.	10	26
TEDI filtered view	2	21
PRORES created	1	15
Instruct. validated	10	
TOTAL	164	116



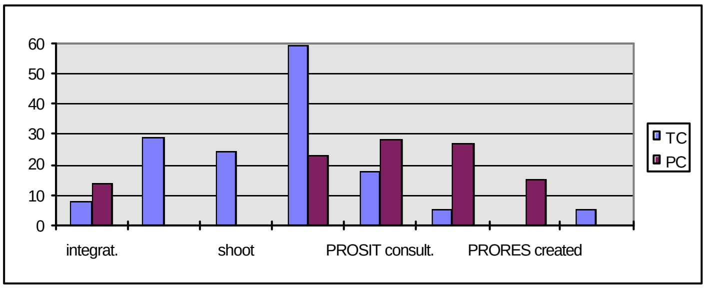
Exo 215	UN / XN	
Fonctions	TC	PC
integrat.	4	21
assume	54	
shoot	38	
extended label	77	52
PROSIT consult.	23	23
TEDI filtered view	4	49
PRORES created	2	10
Instruct. validated	5	
TOTAL	207	155



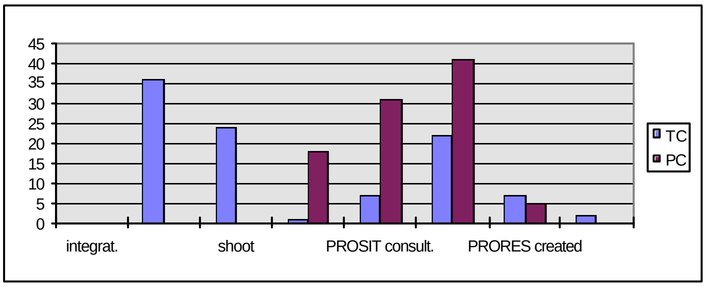
Exo 215	UR / UY	
Fonctions	TC	PC
integrat.	0	24
assume	43	
shoot	29	
extended label	13	4
PROSIT consult.	11	42
TEDI filtered view	55	41
PRORES created	2	11
Instruct. validated	2	
TOTAL	155	122



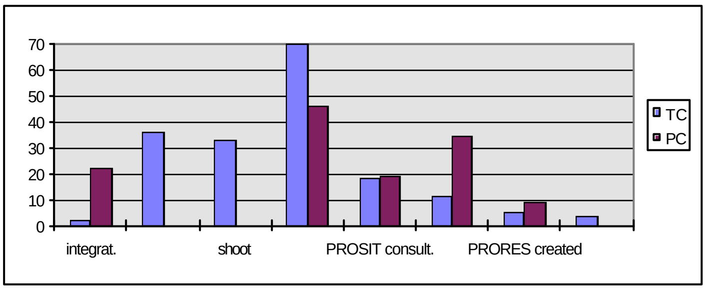
Exo 216	UN / XN	
Fonctions	TC	PC
integrat.	8	14
assume	29	
shoot	24	
extended label	59	23
PROSIT consult.	18	28
TEDI filtered view	5	27
PRORES created	0	15
Instruct. validated	5	
TOTAL	148	107



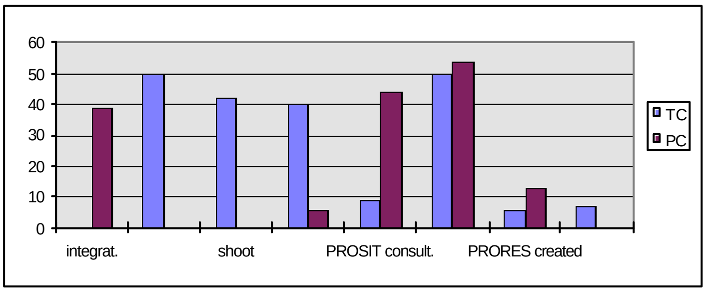
Exo 216	UR / UY	
Fonctions	TC	PC
integrat.	0	0
assume	36	
shoot	24	
extended label	1	18
PROSIT consult.	7	31
TEDI filtered view	22	41
PRORES created	7	5
Instruct. validated	2	
TOTAL	99	95



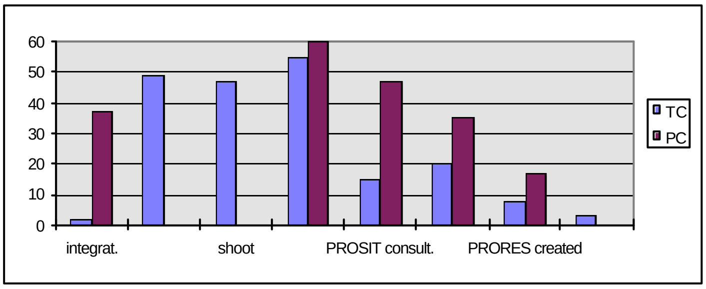
Exo 217	UN / XN	
Fonctions	TC	PC
integrat.	2	22
assume	36	
shoot	33	
extended label	70	46
PROSIT consult.	18	19
TEDI filtered view	11	34
PRORES created	5	9
Instruct. validated	4	
TOTAL	179	130



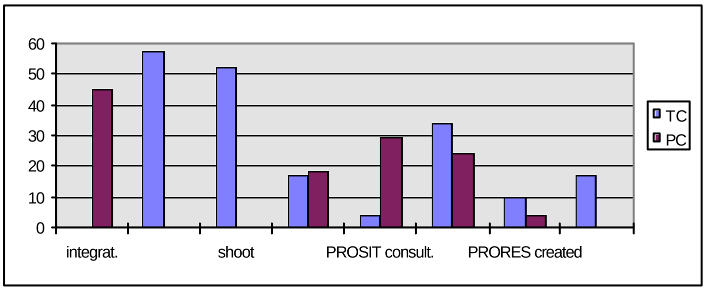
Exo 217	UR / UY	
Fonctions	TC	PC
integrat.	0	39
assume	50	
shoot	42	
extended label	40	6
PROSIT consult.	9	44
TEDI filtered view	50	54
PRORES created	6	13
Instruct. validated	7	
TOTAL	204	156



Exo 218	UN / XN	
Fonctions	TC	PC
integrat.	2	37
assume	49	
shoot	47	
extended label	55	60
PROSIT consult.	15	47
TEDI filtered view	20	35
PRORES created	8	17
Instruct. validated	3	
TOTAL	199	196

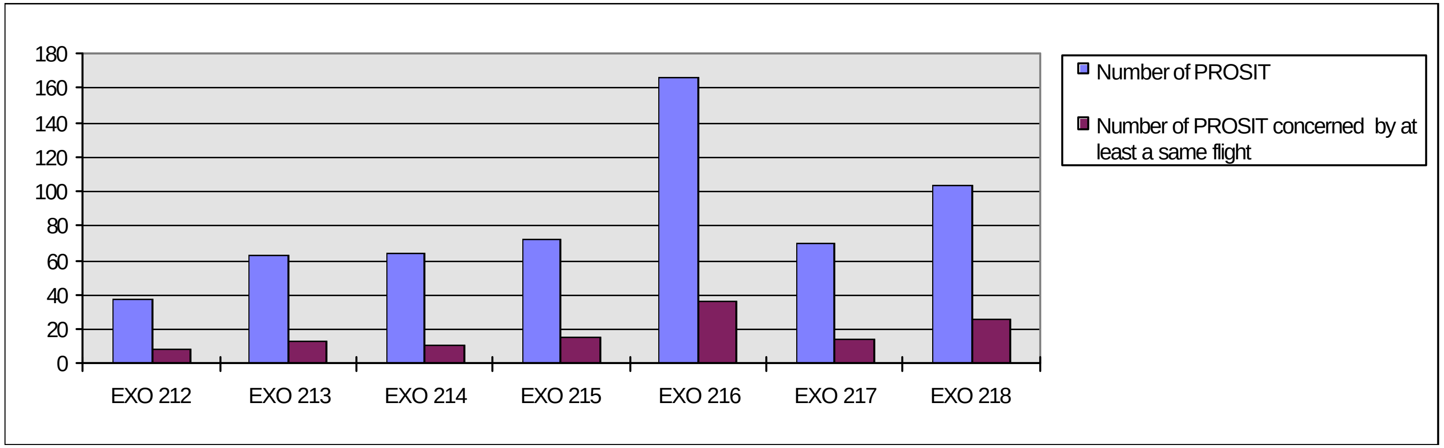


Exo 218	UR / UY	
Fonctions	TC	PC
integrat.	0	45
assume	57	
shoot	52	
extended label	17	18
PROSIT consult.	4	29
TEDI filtered view	34	24
PRORES created	10	4
Instruct. validated	17	
TOTAL	191	120



NUMBER OF PROSIT CONCERNED BY AT LEAST A SAME FLIGHT DISPLAYED AT THE SAME TIME IN THE AGENDAS OF THE TWO SECTORS

Exercices	**Number of PROSIT**	**Number of PROSIT concerned by at least a same flight**	**Proportion**
EXO 212	37	8	*22%*
EXO 213	63	13	*21%*
EXO 214	64	11	*17%*
EXO 215	72	15	*21%*
EXO 216	166	36	*22%*
EXO 217	70	14	*20%*
EXO 218	104	26	*25%*
Total	**576**	**123**	***21%***



16. Appendix G: Ergonomic experts and controllers' suggestion list

Controllers' suggestions:

- APD:
  - Use only one column in the APD in which PROSIT, PRORES and PREPLAB are chronologically visualised,
  - Display the extended PROSIT default drives as soon as it appears with the possibility to close it up when consulted.
- RPVD:
  - Visualise permanently only three pieces of information in the label: callsign, AFL, destination. Other information (CFL, TFL and exit point) could be only visualised on the extended label,
  - Manage the SILs independently because both controllers need to integrate flights.
  - Visualise permanently an electronic stripping (like ERATO),
  - Prefer menu with an elastic vector, easier and more relevant (for example, to enter headings).

Ergonomics experts' suggestions:

- RPVD management functions:
  - Provide easier procedure to use menus,
  - Prefer a direct menu to change heading,
  - Provide an elastic vector while moving the heading.
- RPVD co-ordination functions between controllers of a same position:
  - A planning mark or a different coding has to be displayed even if the PC has not made any modification, so as to show that he/she has well seen the a/c without planning anything for it,
  - Provide functions to support sufficiently the need of information between both controllers.,
  - A specific coding could be developed to show that one of the controllers is working on a flight so as to prevent from confusion,
  - Add a " show proposed trajectory " function between the PC and the TC of a same position.
- RPVD co-ordination functions between sectors:
  - Add a " show proposed trajectory " function between sectors.

- A system support should be available to remind inter-sector co-ordination. For example, each time a co-ordination should be made, the system could visualise a “co-ordinate” message to avoid confusion and forgetting.

- TEDI:

  - The controllers always have to know from which part of the trajectory they can act, by a flip-flop coding on the trajectory for example,

  - Provide a function which allows to modify only a point by moving the clearance marker on the trajectory (like moving a constraint in PD3), instead of reediting a new trajectory for example.

- APD:

  - Allow an automatic transfer of the alarm clock so as to be homogeneous with the PROSIT automatic transfer,

  - Information contained in a PRORES/PREPLAB: prefer the D symbol for a direct rather than the arrow (the same for the H symbol for heading).