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PHARE

EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION, EUROCONTROL

PHARE Advanced Tools Co-operative Tools

Final Report

PHARE/CENA/WBS /SSR; 1.2

EUROCONTROL

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EXECUTIVE SUMMARY

The PD/3 demonstration has been the first opportunity to demonstrate the benefits of the PATs **Co-operative Tools** within the frame of the PHARE full operational scenario: the co-operative tools were not proposed on the PD/1 platform (neither meant to be integrated on the PD/2 platform which was dedicated to the Approach airspace). Nevertheless Co-operative tools had been evaluated twice in the course of the Human Centred Approach Internal Clarification project. The major interest of this PHARE PATs CT final report is to underline the benefits and the limits of the impact of the Co-operative tools, in the context of the PHARE advanced Air/Ground integration scenario.

To understand the CT design approach, it is important to bear in mind that one of the outstanding issues is the evolution of picture formation and traffic awareness, in a context where the controller has to be maintained in the control loop to improve the **joint man/machine performance.**

The specific features of the CT user requirements emphasise **information filtering, team resource management and traffic memorisation and surveillance**. This is achieved through two major subfunctions called **interactions** and **problems** detection modules**.** In the user interface, these functions feed the filtering device of the Plan View Display (radar image) and the Activity Predictor Display, which is a CT dedicated display permanently available on the en-route sector. The principle of the co-operative tools is to detect potential traffic problems (set of one or more interactions, called PROSIT) and to present them as a timely ordered planning in the Activity Predictor Display; each displayed PROSIT can be clicked to highlight the involved aircraft in the Plan View Display, so as to assess its relevance and time stamping.

During the implementation and integration processes, the major source of complexity has been the necessity to maintain consistency between the computed results and the updates input by the planning controller. This interactivity makes the Co-operative Tools more complex to evaluate than other PATs, because it needs to be tested during the final integration phase.

Another very important subject had to be given up, due to the delayed integration tests: the adaptation of the CT to the ETMA position. Thanks to the early use of the CT software in the Human Centred Approach IOCP (starting in 1996), some performance and CMS interface problems have been solved (notably through allocating a set of CT processes to each control unit and through optimising the use of CMS trajectory API).

The level of maturity achieved on the CT version proposed to the en-route controllers during the PD/3 experiments was highly satisfactory. The major limiting factors for observing significant gain in the fields of workload and quality of service are the complexity of trajectory handling and negotiating.

Nevertheless, the thorough observation of the control activity performed during the experiments has confirmed that **CT provide a valuable support to risk assessment**, **enhance anticipated planning and alleviate traffic surveillance**. The items still to be investigated are the operational gap that appeared between the planning and the tactical controllers and the difficulty to memorise the contracted trajectories.

Look in back to all earlier CT experiments (IOCP), it worth mentioning that the first reservation (insufficient co-operation support) had not been noticed, but the second one (memorisation difficulties) was already a matter of concern. This indicates that the complexity of trajectory negotiation and computation is not the only difficulty; another one might well be level of trajectory freedom achieved through these functions.

For the future, it seems very important to adapt the principle of filtering the information to the traffic structure of the ETMA. This was a request from the controllers who had to man this position during the experiment. Better harmonising the understanding of the constraint concept is also vital and will improve the PATs consistency (CT/PS in this context). It also will ease controller trajectory handling and memorisation.

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1 INTRODUCTION

1.1 SCOPE

This document has been produced as part of the PHARE Advanced Tool Set (PATS) project within the PHARE program.

1.2 DOCUMENT CONTEXT

The document is the final report for the PATS Co-operative Tools and forms part of an overall document containing final reports on all the tools within the PATS tool set.

1.3 OVERVIEW

It is the purpose of this document to give an overview of the Co-operative Tools (CT) functions and capabilities, in the context of the global PHARE concept, to recall the requirements and to present the experience gained through implementation and experiment phases.

The Co-operative Tools are a ground based set of tools designed to enhance the way En-Route controllers apprehend an Air Traffic Situation. The principle of this support is an intelligent filtering function based on algorithmic rules, sorting out the information presented to the control team at a given time, depending on the traffic problem a PC or a TC is actually working on. A support is also given to process this problem by priority. The problem detection is a built-in function specific to the CT.

1.4 REPORT STRUCTURE

Section 2 describes the operational concept of the PATS Co-operative Tools.

Section 3 describes the requirements for the PATS Co-operative Tools.

Section 4 describes the implementation of the PATS Co-operative Tools.

Section 5 describes the usage of the PATS Co-operative Tools.

Section 6 describes and interprets the results of real time trials relative to the PATS Co-operative Tools.

Section 7 provides conclusions and makes recommendations for future work utilising the PATS Co-operative Tools.

Section 8 provides definitions of terms and references used throughout the document.

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2 OPERATIONAL CONCEPTS

2.1 OPERATIONAL CONCEPT

2.1.1 Context description

The PHARE system simulated the control of aircraft flying over the western part of European airspace, in an area where traffic density and complexity is one of the highest in Europe. The density of the simulated traffic was as anticipated in the years 2015 (longer peaks of traffic, with an instantaneous traffic load 1.5 to 2 times equal to today' peaks).

Increasing traffic density means increased ATC systems data volume and complexity. Today ATC system performance is already limited by the volume of data a human operator can manage at the same time. In the PHARE environment, the information will be much more predictable. But "unforeseen situations" are the major source of complexity in control activities and the human operator is the best at coping with the unexpected.

The question to be raised is:
"HOW TO IMPROVE THE JOINT MAN/MACHINE PERFORMANCE ?";
and a good path towards the answer is :
“TO FIND THE LEVEL OF INFORMATION NECESSARY AND SUFFICIENT FOR THE CONTROLLER TO BE ABLE TO TAKE THE RIGHT DECISIONS AT THE RIGHT TIME”.

2.1.2 The Co-operative tools in the PHARE Operational Concept

The Co-operative Tools is a way to provide this information to En-Route control positions : assess the risk of any potential problem to better and earlier adjust the team strategy is a new way to build the image of a traffic situation.

- A PROblem SITuation (PROSIT) is either involving aircraft actually conflicting or aircraft being legally separated although a deviation would immediately cause a problem. A problem filtered view is obtained through highlighting the relevant sub-set of aircraft.
- The activity predictor is a planning of the pending problems.
- The task sharing is guided by the activity predictor.
- The anticipation is enhanced by the early highlighting of problems.

2.1.3 Technical context description

The CT uses the following sets of services :

- Trajectory
- Co-ordination
- Area of Common Interest
- Constraint
- Configuration (sector to control unit association)
- Flight Plan
- Time
- Surveillance

The detailed description of the semantic and dynamic dependencies between the CT and these services are detailed in Ref [2]

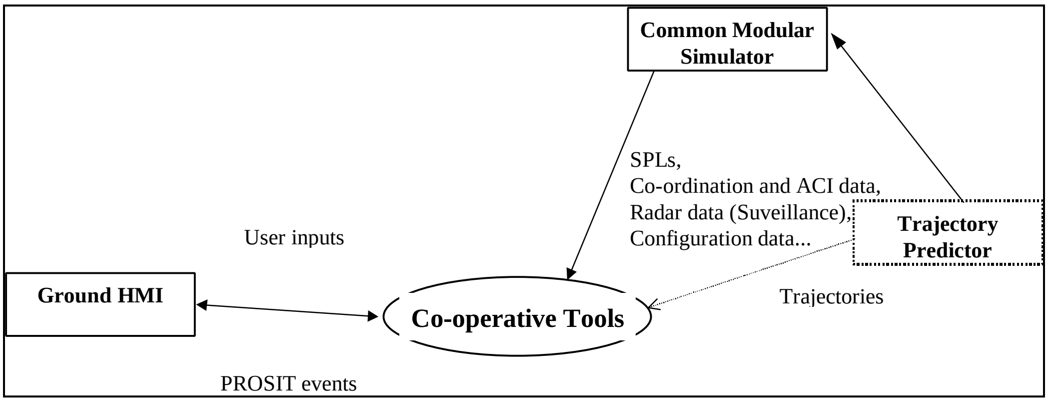

Figure 1: Context Description

2.1.4 Interface with GHMI of En-Route Controllers

The CT supplies the RPVD with subsets of aircraft that are involved in a PROSIT (these aircraft are highlighted on request) and the Activity Predictor Display with the list of potential problems with a name and a time stamp.

The CT manages the interactions with the APD by taking into account controllers' updates on the list of problems (deletion or time stamping change).

2.2 DEVELOPMENT PROCESS

2.2.1 History of Tool Development

The PATS CT project was initiated in 1993 and led by CENA to study the use of ERATO concepts in PHARE. The URD of the initial version was produced by CENA in 1994 (Cf. Ref. [0]).

The tool was developed in several steps:

1993 -April 1996: Design and development of ERATO (Internally developed advanced tool) raw functions for a single position.

April 1996 - July 1996: Upgrade of CT algorithms and architecture for En-Route multi-position purpose, use of LOA in CT algorithms. Use in IOCP HCA Step 1a.

July 1996 - April 1997: Upgrade of CT algorithms to manage ACIs and integration of D/L aircraft and D/L clearances in IOCP HCA Step 1b.

April 1997 - March 1998: Upgrade of CT algorithms for PD/3 Pilot Phase. Integration with the NM, the PS and the CP, use of airborne trajectories including SIDs and STARs parts, integration of flights in a CT position 10 minutes before planning authority.

March 1998 - June 1998: Tuning of CT parameters for PD/3 Main Phase.

2.2.2 Why it was developed that way

At the beginning of the PHARE project, it was essential to consider Human Factors, because the set of PHARE Advanced Tools involved a considerable technological step introducing significant changes in the controllers' activity.

The ERATO project was considered as a valid starting point for CT design and development: it had been designed with the objective of maintaining the human operator in the decision loop and was supported by a rigorous cognitive engineering study of the En-Route controllers` activity.

From a conceptual point of view, the improvements that had to be brought to the existing algorithms to fit to the PHARE context were:

- take the Area of Common Interest into Account;
- ensure inter-sector PROSIT consistency;
- take the PHARE 4D trajectory concept into account.

From a technical point of view, the development of this PATs was eased by an incremental approach, where the target platform of the IOCP version was already compatible with the final platform; this saved effort on integration tests.

2.2.3 Dropped ideas and concepts

- Feed a Look Ahead Display with the filtered information given by the CT.

  This was the reason why CT were fed with flight information before the planner controller received the planning authority, but, due to lack of time, the Look Ahead Display was not developed in DAARWIN platform.
- Use Conflict Probe outputs instead of CT to built-in an Interaction Detection function : this was given up for two different reasons:
  a) CP outputs did not meet the requirements of the Activity Predictor function
  b) from a conceptual point of view, it was considered that CP and CT output were not to be used by the controllers within the same time horizon (the CT provided an early global risk assessment whereas the CP was purely geometrical and fitted well short time ahead conflict monitoring)
- Introduce a cross check between CT and Problem Solver filtered information to enhance consistency. This had to be postponed, due to lack of time.

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3 REQUIREMENTS DESCRIPTION

The following descriptions represent an overview of the current core requirements.

3.1 USER REQUIREMENTS

The main characteristics of the operational context of PHARE are broadly presented in Ref. [3] . To ease the understanding of the general description of the CT, the major elements of the scenario are repeated below:

- Air/Ground integration (Data Link applications)
- Human centred approach (Tools design philosophy)
  - Enhance information filtering
  - Enhance work plan management
  - Make team co-operation more efficient
  - Support memorisation and monitoring tasks
- Traffic management philosophy (application of 4D navigation)
  - Work by anticipation (4D guidance capabilities of aircraft)
  - Traffic organisation in Multi-sector planning context (ATC organisation)

It is anticipated that the CT will be used at en-route control positions, and will be used by both controllers (PC and TC) working as a team and sharing the work. The PC is responsible of a early planning before the aircraft enters the sector and acts as a radar assistant after the aircraft has entered the sector, the TC is responsible for control and monitoring for the flights currently within the sector.

3.1.1 Work by anticipation and team co-operation

The PC will be able to work by anticipation, thanks to better-guided trajectories. It is expected that the Co-operative Tools will support the planner by filtering the available information before the aircraft reaches the sector boundary and is transferred to the TC. So the instantaneous situation and further progression of this aircraft will be better assessed.

3.1.2 Enhance information filtering

The principle of filtering is to display subsets consisting only of those aircraft that contribute to a complex traffic situation.

3.1.3 Enhance work plan management

Knowing the subsets of aircraft that will have to be monitored during the next 15 minutes enables the control team to better organise their work by sequencing the handling of these problem situations.

3.1.4 Support memorisation and monitoring tasks

Structuring a complete traffic situation into subsets of aircraft supports the monitoring and memorisation activities of the TC, enabling the handling of an increased number of aircraft.

3.2 FUNCTIONNAL REQUIREMENTS

The two high level functions of the CT are:

- **Interaction detection**: checking aircraft against each other in a "controller like way" and qualifying the interactions[1] between them.
- **Problem detection**: regroup these elementary interactions in sets of aircraft that can be handled as a consistent "Problem Situation" by the controller and time stamp it.

The controllers` HMI is fed by both processes, it has to produce either subsets of aircraft interfering with a given aircraft (to be used while considering a flight, or when searching for a tactical manoeuvre to avoid a short term conflict), or sets of aircraft involved in the same conflict situation (to be used for complexity assessment and work plan management).

The Activity Predictor Display is fed by the problem detection process. The problems have to be given a name (which is a summarised description of it) and a time stamp (which enables the controller team to organise problems between them).

3.2.1 Interaction detection detailed capabilities

The first questions to be answered by the system are "could this aircraft become a matter of concern for the ATCO? If so, when, until when and why?” An aircraft is considered as preoccupying if it may interact with other aircraft.

It is considered that aircraft may "interact" in two ways:

- at a given time, they may require additional attention because their trajectories are too close;
- one of them may be a constraint if the ATCO decides to change the trajectory of another (also called : "restricting" aircraft).

To detect these interacting aircraft, the system has to perform the following functions:

- assess the risk of interaction between two aircraft, through making a prediction of potential deviations and their probabilities;
- assess if an aircraft is restricting another one.

Compute the vertical profile of each aircraft

The top level requirement for this function is not to give a trajectory profile which is to be flown by the aircraft but of the way the flight is mentally represented by the ATCO. The main differences between those two "objects" is the **handling of the known context by the ATCO**: for climbing or descending flights, the ATCO works with markers, like segments between named points and cleared or targeted flight levels. He does not make abstract calculations about geometrical data (height or horizontal position). Aircraft profile is handled in a kind of "macro" reasoning that can translate information as "the IT310 will clear his level before GAI" , "the SWR400 will be levelled off [at 310] between RLP and CTL"

The resulting profile is implemented as a staircase with as many steps as significant flight levels (parity, cleared or co-ordinated, actual (SSR)).

[1] **Interaction** is the world used within the Co-operative Tools project to speak of both conflicts (certain or possible) and cases where one aircraft is a constraint for another in case of maneuver (called "restricting" aircraft).

Compute the along track behaviour of the aircraft

As far as the time dimension is concerned, the ATCOs work with estimated times over beacons (available through flight plan information). The accuracy of the controllers' reasoning is based on "round minutes" and what is important for them is to be sure that whether the aircraft will be before or after a beacon at a given time (rather than knowing its precise position):

- starting from a Time 0 given by the trajectory predictor, the ATCO mentally dates the points with "certain" temporal markers.
- Time 1: the time before which it is sure that he aircraft has not reached the point.
- Time 2: the time after which it is sure that it has passed the point.
- The way Time 1 and Time 2 are derived from Time 0 may depend on "rules" as "is the considered position far from now"

Detect whether aircraft interact vertically

Aircraft interact vertically if the representation of their vertical profiles intersect, and, if, during the period of intersection, the flights also intersect in time.

Detect whether aircraft interact horizontally

To be compliant with the controllers' reasoning, this process must follow the following steps:

- Find proximity points between trajectories (2D)
- Define a 2D critical area around these points, one around each trajectory, the length of the area along each of the four trajectory segments depends on the angle between these segments : this is the area within which the lateral proximity between aircraft may be a "matter of concern" for the controllers:
- Taking flight direction and time into account, check whether both aircraft may be simultaneously in the critical area. This is the part where rules inherited from controllers' reasoning are the most important. According to relative angle of each pair of trajectory segment and flight direction, the along track separation threshold taken into account is different: e.g.: if the angle is small and aircraft fly opposite directions, the separation to respect will be higher.

3.2.2 Problem detection detailed capabilities

Once interactions are detected, the system has to build subsets of aircraft that can be handled as a whole by the controller.

- associate more than two interacting aircraft creating a PROSIT.
- qualify each problem in order to make it explicit.

The system has to present a list of problems that can be considered as a comprehensive view of the traffic situation. If the ATCO whishes to edit this view to change some of the subsets (add or remove an aircraft from a subset) or even to remove entire subsets, the system has to take these changes into account when it updates the situation.

3.2.3 Find the Interaction that can be part of a PROSIT

The grouping heuristics are based on interaction qualification (crossing, same way, face to face), aircraft phase of flight (climbing, levelled, descending) and manoeuvring areas (that also depend from interaction qualification and the phase of flight).

Then, the following rules are applied:

- If an interaction involves a climbing or descending aircraft, all other interactions involving this flight are associated to it , provided that areas for resolution manoeuvre associated with these interactions intersect with the climbing segment of the trajectory;

- Two interactions with the same horizontal configuration are associated if their manoeuvring areas intersect,

3.2.4 Give a name to a PROSIT

The **name** of a PROSIT derives from the association rules that enabled to form it and from its location (nearby beacon or airport and level). The association rules can generate several kinds of problems:

- crossing
- face to face
- same way
- climb
- descent

3.2.5 Give an overall view of the situation

The algorithms of PROSIT detection should aim at structuring a global traffic situation, which must be comprehensive and eliminate redundancies (same interaction appearing in several problems).

3.2.6 Give the limit time of a PROSIT

It is the time after which the problem will be more difficult to solve. It's computation should be based on manoeuvring areas: for each kind of PROSIT this area is defined in a way that it is supposed to be representative of the most time demanding manoeuvre, the time of the first significant aircraft entering this area is the limit time of the problem.

3.2.7 Give the responsible control unit(s) (sectors)

This has to take into account the location of the interactions along aircraft trajectories (outside sector, in sector Area of Common Interest, in sector) and the co-ordination status of the flights (assumed in the reference sector or not).

3.2.8 Ensure PROSIT inter-sector consistency

In the Area of Common Interest, PROSITs involving the same interactions have to be provided to the ATCOs of the various control teams in a way that enable them to use these PROSIT to support co-ordination dialogues: PROSITs must be provided at the same time on the different control units, they must also have consistent names.

3.2.9 Take ATCOs' changes into account

The generic problem set provided by the system has to be reworked by the controller team to fit their actual own work plan. Taking ATCOs' changes into account depends on the HMI functions available and on the ability of the system to take inputs as criteria, which influence the update of the list of problem subset in priority.

3.3 IMPLEMENTATION DEPENDENT REQUIREMENTS

3.3.1 Integration

The tool has been successfully integrated into the DAARWIN platform at CENA and into the ESCAPE platform at Eurocontrol.

APIs are provided through a CMS compliant server.

3.3.2 Client / server architecture

The tool has been developed to work on a client / server architecture.

The tool has been developed to allow communications synchronously or asynchronously. In this way, delayed responses to requests for data made by the tool do not delay processing of other inputs.

3.3.3 Platform independent

The tool has been developed so that there is no reliance on any underlying operating system (for example, UNIX). The developed software does not make reference to platform specific functions.

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4 IMPLEMENTATION

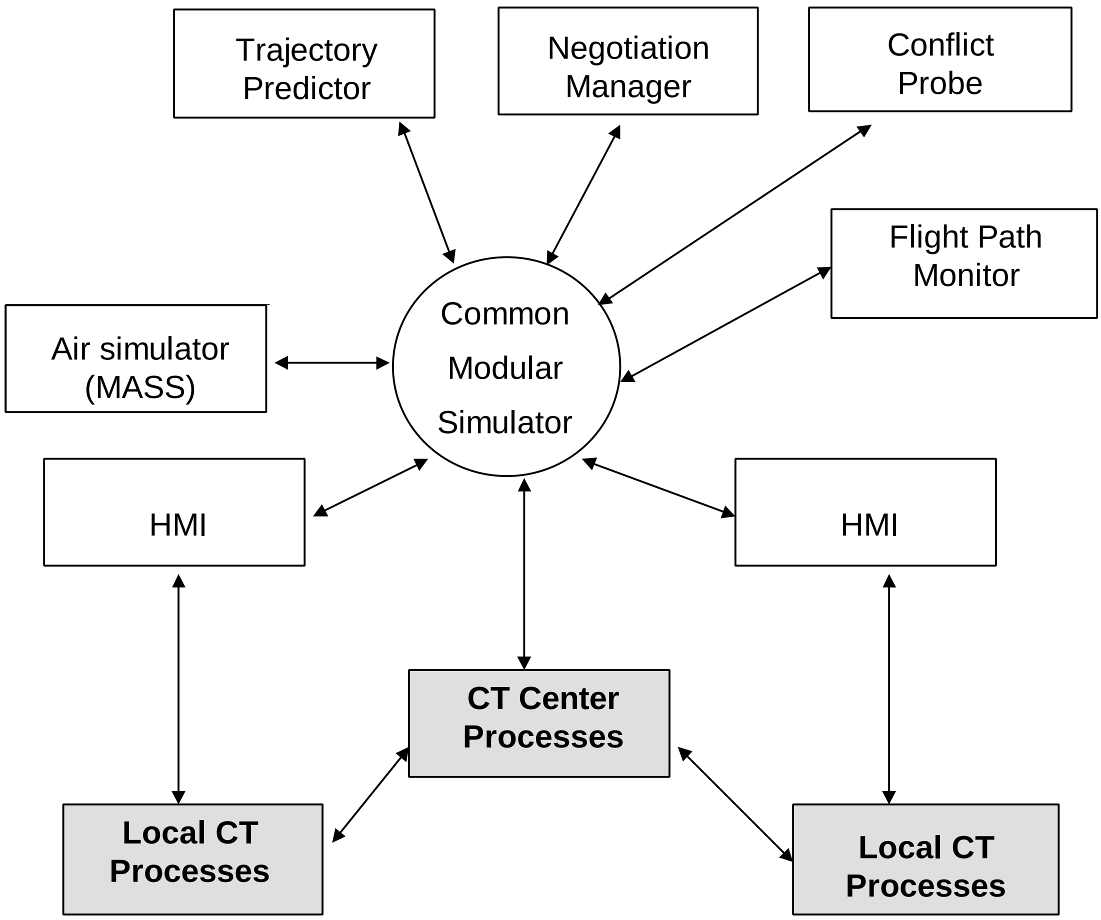
4.1 HOW DEVELOPED

Following an initial research period, a mock-up was designed and developed using Ada programming language. For the design, an object-oriented methodology elaborated at CENA was used. Some components of the ERATO tool were re-used and adapted.

The integration into CMS environment was performed from the beginning: CMS middleware was used to build clients and servers. Two data servers have been developed (ERATO Centre server and ERATO server) and clients such as interaction detection are connected on them.

Ada language was used for the development of the servers and CMS standards were followed for the generation of the APIs (APIs of servers are also generated in C). Clients are developed in Ada and C++ languages.

The final integration into the PD/3 platform, consisted mainly in feeding CT algorithms with trajectories issued from trajectory negotiation process.



4.2 TECHNICAL ENVIRONMENT

Ada and C++ languages have been used for the development of CT components. The source code is available at CENA on a UNIX file server accessed from a network of SUN / DEC UNIX workstations. Modifications to the source code have been managed using the CVS source code control tool.

4.3 PERFORMANCE ISSUES

4.3.1 Interaction Detection function for high traffic samples

Interaction Detection function can be used at **centre** level or at **sector** level. As the interaction function is time consuming, the PD/3 experimentation was built with a CT architecture where all CT units had their own interaction detection function.

4.3.2 Trajectories updates

A negotiation cycle can be long between an initial trajectory edition and the CT PROSITs updates. Datalink communications, Negotiation Manager checks and both air and ground system computations had to be improved to avoid operators' frustration.

4.3.3 GHMI inputs handling for PROSITs

Interactions between GHMI and local position CT servers for PROSIT management are quick, no performance problems were noted from this point of view.

4.3.4 Internal Databases and events Management

Hash-tables were used instead of sorted lists to optimise internal data storage and CT data subscribers`management.

4.3.5 Retrieving Data from CMS ground system

CMS/CT gateway did not subscribe to all events notifying flight data update such as constraints, trajectories, ACI, co-ordination data. On receipt of a terminating event signalling the end of the transaction, all data needed for RPC was retrieved from the CMS servers. As these RPC are synchronous, to avoid poor gateway performance, the flights being processed were marked, and another - not locked- flight was processed. This allowed the simultaneous processing of several flight updates optimising the gateway.

4.4 PROBLEMS FOUND AND SOLVED

4.4.1 PROSITs Names too long

A previous CT version provided PROSITs names as a 20-character string. This string was computed by CT local server, from the interfering altitudes ranges of the PROSIT and, the horizontal location of the PROSIT (beacon name or airport). The GHMI team recommended that the PROSIT name on the Agenda Primary Dsiplay should be shortened and based on exported data.

4.4.2 Management of altitude constraints in SIDs / STARs

CT interactions in SIDs / STARs were not always valid especially from the vertical point of view, Constraints Management in SIDs / STARs seemed to be platform dependent. In order to upgrade vertical detection in TMA phases and stay non platform dependent, it was decided to compute SIDs / STARs altitude steps useful to CT trajectory representation directly from the ground system trajectory object, and not from SIDs / STARs altitude constraints.

4.4.3 Re-entrant flights leading to unexpected flight deletions

Sometimes flights were deleted too early at a CT way point position. This was due to re-entrancy problems (i.e. the flight can cross the CT position more than once). It was decided to delete the flight at a CT way point position only when the flight was not relevant for the last occurrence of that CT position.

4.4.4 PROSITs Responsibility

Some PROSITs were incorrectly displayed at a CT position when they had been solved. New CT criteria for conflict location were implemented for conflicts at entry boundaries, masking PROSITs which should have been solved by previous controllers. However, aircraft with conflicts at sector entry were always visible as restricting aircraft.

4.5 UNSOLVED PROBLEMS

4.5.1 Use of CT in ETMA

The PROSITs in ETMA were too large to be relevant due to:

- separation criteria of interaction detection function;
- use of ACIs;
- influence of TMA departure and arrival sectors.

There was no time to study CT behaviour in ETMA, as it could be a study in itself, because CT algorithms were originally designed for upper En-Route sectors in ERATO project. Therefore, in the PD/3 experimentation, CT was not used in ETMA.

4.5.2 PS / CT / CP Co-existence

The PS and CT have their own conflict detection function. Occasionally the results differ with only one identifying a conflict. There was insufficient time to find the reason why this occured.

4.6 LESSONS LEARNT

- **Complex integration phase**

During the implementation and integration processes, the major source of complexity was the necessity to maintain consistency between the computed results and the updates input by the planning controller. The planner had to sort out the automatically detected problems before the aircraft entered the sector by assessing the real risks. This interactivity made the co-operative Tools more complex to evaluate than other PATs, because it made it essential to perform long integration tests.

- **Understanding of the concept of trajectory constraints**

In the context of PD/3 the concept of constraints was a critical one (due to its complexity) and had to be fully understood by the CT development team because of the importance of the prediction of aircraft vertical behaviour for the interaction detection.

- **PROSIT/sector association**

Two issues required the bulk of unplanned effort during the PD/3 final integration phase: careful monitoring of the updates of flight states, so as to present the corresponding CT situation in a given control unit and the allocation of the detected interactions and problems to the relevant control unit.

- **ETMA CT need specific algorithms**

Tuning the algorithms designed for the En-Route position was not satisfactory. It seemed that adapted specific algorithms were necessary.

4.7 OPERATIONAL USAGE

What follows is first a description of the general layout of the CENA PD/3 simulation from an operational point of view, to understand the context in which the CT were used. Then, a short description of how the controller team was supposed to adapt its work to use the support given by Co-operative Tools in the context of the PHARE operational scenario guidelines is provided. These are the operating methods that were suggested to the controllers during the training phases.

4.7.1 Co-operative tools in the context of the general lay out

The CENA PD/3 platform comprised three measured positions. Although CT were initially planned to be integrated in both en-route and ETMA positions, they could only be utilised on the en-route position.

During each run, the CT were actually used by 4 controllers out of 9: the PC/TC of the measured sector UN/XN and the two controllers of the upper feeder sectors (UR/UY and UZ/ZU).

4.7.2 How to operate the CT through PD/3 GHMI

- **Operating the filtering device**

By clicking a PROSIT label on the APD, aircraft involved in this problem situation were highlighted on the RPVD.

- **Operating the activity predictor**

The Activity Predictor was an interactive planning where tasks were control problems (PROblem SITuations with at least 2 aircraft). These tasks were represented by a named label with a time stamp which enabled the arrangements of tasks along the time axis .The time horizon of the planning was ~25 minutes ahead of the current time. Each problem was located according to its **"limit time"**, thus, a problem reaching the bottom end of the display was considered as the most urgent.

Information implicitly displayed:

- global planning display of problems
- the strategic and tactical areas of the APD. The display policy was not the same on both controllers working positions: the display could be divided vertically in two zones: the tactical area and the strategic area. If the limit time of a problem was between current time and ~6 minutes in the future, it was in the tactical zone, if it was between ~6 and ~25 minutes in the future, it was in the strategic zone. All the problems detected by the electronic assistant were displayed to the PC, whereas the implicit policy was to only provide the TC with problems, if they still existed when they "reached" the tactical zone. It was possible for the PC to make problems visible in the strategic zone of the TC display, but this needed to be done via an explicit "label transfer".

One problem label on the APD was composed of the following fields:

- number of significant aircraft
- type of problem (crossing, face to face, overtake (same way), climb or descend)
- location (beacon (or airport for climb and descent problems).
- flight level (in case of a levelled aircraft)

Manual input was enabled allowing the APD display to be made consistent with representation:

- erase one PROSIT label (if not relevant with the PC strategy)
- change the time stamping of PROSIT : when a label was selected, the floating field "time" of the label could be captured, this made the RPVD switch into "Look Ahead" mode : the trajectory of each significant aircraft of the problem was displayed and a dynamic marker appeared on each of these trajectories. The marker was initially located at the point that would be reached by each of the aircraft at the limit time of the problem. If the problem label was dragged along the time axis , the **trajectory markers moved accordingly**, the controller only had to drop the problem label when the markers were at a position that he considered as the time for action to be taken.
- project a filtered situation in time and move the involved aircraft along their future path (see preceding bullet).

- **Support to inter-controller communication**

This support was based on the transfer of a problem label earlier than the TC zone and on the availability of the same PROSIT label on both TC and PC APD.

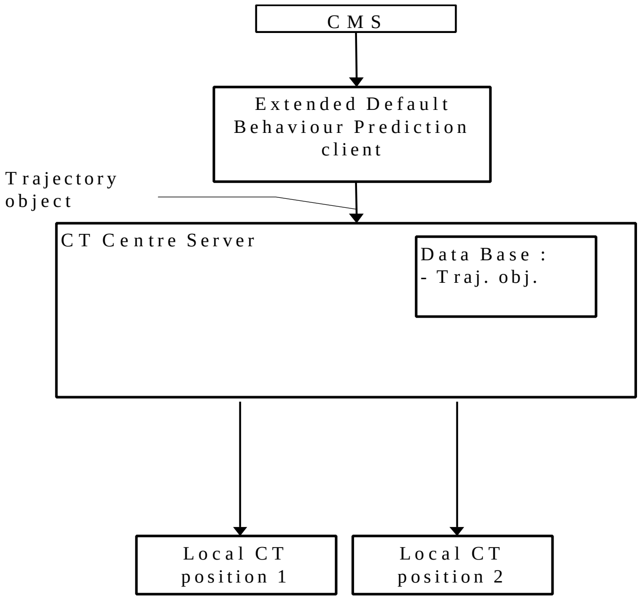
4.8 TECHNICAL USAGE

The Co-operative Tools were integrated into CMS environment. Any use by an other tool needed to go through the ERATO Server either to retrieve outputs and events generated by the CT or to interact with it.

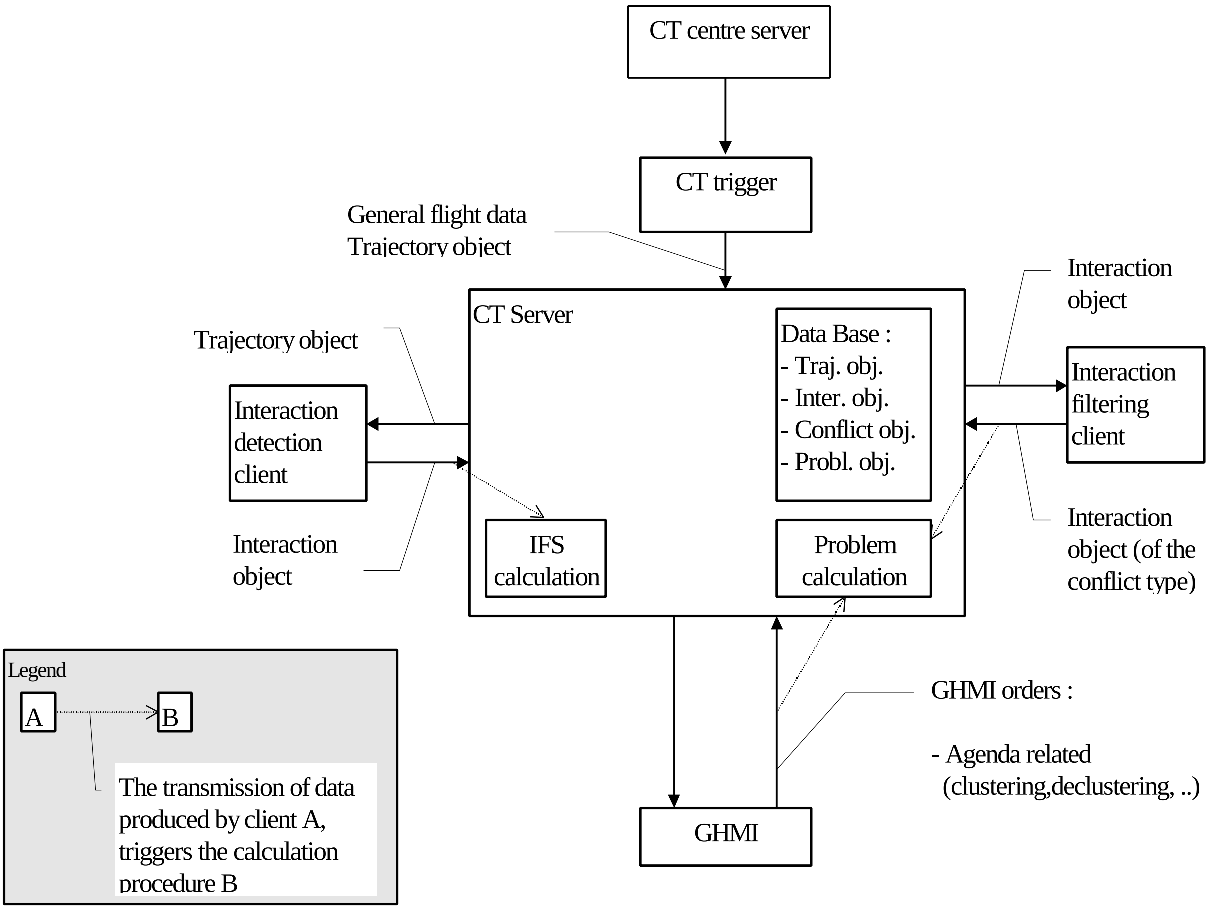
The Co-operative-Tools were divided into two groups of processes:

- the Centre part: managing the connection with the CMS system and the distribution of CT data (creations, updates, deletions) useful to CT positions, according to flight states in managed CT positions.
- the Position part: managing data useful for ATCOs (TC and PC) for a given position. CT data produced at this level are IFS and PROSITs useful to GHMI.

The following figures show more precisely how CT processes were distributed:



Centre CT processes.



Local CT processes.

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5 RESULTS

5.1 IOCP TRIALS AND TEST RUNS

5.1.1 Recall on the IOCP operational contents

The IOCP experiments took place in April 1997 for two weeks. They involved four controllers.

The simulated airspace comprised two upper en-route sectors (Reims ACC UR/UY and UN/XN).

The CT were already capable of a full set of functions, but the control position was not fully compliant with PD/3 operational scenario requirements: only a limited simulated negotiation (only route clearances) and no system supported co-ordination.

5.1.2 CT IOCP results

As far as the co-operative tools were concerned, the most positive points put forward after the Human Centred Approach IOCP experiment were:

- the ability to filter the traffic subsets of traffic;
- the use of the projection in time of a filtered situation (this function is available in the PD/3 set under the name "extrapolation");
- PC/TC communication support given by the use of the Activity Predictor.

The filtering function still had to be tuned carefully, to come to a satisfactory set of contextual aircraft.

A more comprehensive description of the results is provided in Ref.[4]

5.2 PD/3 DEMONSTRATION

This was the first experiment where the CT were demonstrated within the frame of full PHARE PD/3 concepts. How the CT were operationally and technically integrated in the PD/3 control position is described in Section 4.7.

5.2.1 CT evaluation objectives

The available PD/3 evaluation results proposes to examine the benefits of the advanced tools, following three major axis:

- handling on position
- co-operation aspects
- co-ordination/negotiation aspects

The CT was aimed at bringing a support in the context of the first to dimensions of the activity: handling on a position (through memorisation and organisation support) and co-operation.

5.2.2 Positive results

The observations and debriefings performed during the experiment runs already brought an overview of the results (that will have to be confronted with the synthesis of measured data):

- the traffic structure given by the activity predictor was a good support to encourage anticipated planning by the PC;
- the principle of filtered view was appreciated and is essential to assess early the level of risk of a given conflict situation and alleviate surveillance tasks;
- the suggested working method that consisted of checking the relevant conflict situations (provided in the Activity Predictor) while first taking a flight into account was generally put into practice by the controllers;
- as foreseen in the operational scenario, the CT were a good support to analyse and memorise a situation, before the resolution phase, during which the PS had to be used.

5.2.3 Areas to be further investigated

- **Support given to team co-operation by the Activity Predictor in the context of anticipated planning:**

As mentioned above, the use of the activity predictor was a good prompt to enforce PC early planning, **but**, so far as the PC/TC co-operation is concerned, improvement is still required: in the context where PC and TC work in different time frames, and on different traffic, they tend to become isolated, and in periods of heavy workload, the co-operation was degraded in spite of the support given by the APD.

It should be noted that this phenomenon was not observed during the IOCP experiment, during runs involving a comparable amount of traffic. One explanatory hypothesis is that the PD/3 trajectory editor was more comprehensive than the IOCP editor (vertical manoeuvres) and the PD/3 negotiation was more time demanding. The overall planning process was a heavier workload and took more time in PD/3.

Furthermore, it is essential for the TC to be able to see very quickly if the trajectory of a given flight was replanned by his PC or not; this information was available on the IOCP GHMI, but not in the PD/3 GHMI.

- **Difficult to concentrate both on APD and PVD:**

The use of the activity predictor became an essential part of the PC activity, but to efficiently act as a TC assistant, the PC also had to be able to switch to the radar view permanently. In fact, some controllers found it difficult to concentrate on two information windows at a time and the TC found it necessary to recheck all the aircraft.

- **PROSIT availability to be better synchronised with flight availability:**

Although this function was finally not available, the time requirement of the Look Ahead display had been taken into account while integrating the CT to the CMS platform. This meant that the CT started to process a flight not at ten minutes before its arrival, but twenty minutes before sector entry (proposed rest position of the PC PVD/APD according to LAD requirements). This caused PROSITs to appear in the APD sooner than the actual plannable state of all involved flights. This often disturbed the controllers and made the surveillance support less efficient than it could have been.

- **Enhance tools consistency:**

The operational scenario suggested a phased use of CT and PS; this proved to be successful but the occasional discrepancies between the tools sometimes proved to be disturbing to the controllers and, more importantly had a negative impact on the level of user trust in the tools.

5.3 ACHIEVEMENT OF CONCEPT

5.3.1 Areas achieved

The CT proved beneficial from the point of view of traffic surveillance and organisation.

5.3.2 Areas not achieved

Traffic awareness and memorisation still have to be improved in the complex context of free trajectory editing and negotiating

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6 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The PD/3 demonstration was an opportunity to adapt the design of the Co-operative Tools (human centred) to the highly technically driven context of other PHARE Advanced Tools.

The CT capabilities were enhanced to meet the requirements of anticipated planning and to take advantage of the availability of equipped aircraft trajectories in the ground system. However, it was a very positive achievement to keep the original principle of taking a certain level of uncertainty into account while modelling the global set of aircraft trajectories. This enabled the use of a set of Assistance tools that could be operated in sequence by the controllers: an anticipated risk analysis supported by the Activity Predictor and a short time resolution supported by the interactive Problem Solver.

The need of a global efficient view of a current and coming traffic situation also seems to be emphasised by the practice of trajectory edition and negotiation. This raises the issue of picture formation, which is very dependent on traffic patterns and flows today. The capability of displaying a filtered situation ahead of time is a good candidate to support this picture formation in a more flexible airspace. Its design and development has to continue to take advantage of any upgrade of the Trajectory Prediction facilities.

Moreover, the technical success of the demonstration brought an evidence of the CT feasibility in a high traffic load situation.

6.2 RECOMMENDATIONS

6.2.1 Adapt CT to the ETMA environment

The CT concept proved to be successful, but adapting CT to the ETMA context proved to be harder than parameter tuning and could finally not be achieved within the PD/3 time frame. It seems that some parts of the interaction detection function have to be redesigned in depth, notably the handling of sequenced aircraft on the same SID.

6.2.2 Better ensure inter PATs consistency (CT, PS)

The operational scenario suggested a phased use of CT and PS; this proved to be successful but some discrepancies between the tools sometimes proved to be disturbing to the controllers and, above all, had a negative impact on the level of user trust to the tools

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7 ACRONYMS, DEFINITIONS AND REFERENCES

7.1 ACRONYMS

ACI	Area of Common Interest
API	Application Programming Interface
APD	Activity Predictor Display
ATCO	Air Traffic Controller
CFL	Cleared Flight Level
CMS	Common Modular Simulator
CP	Conflict Probe
CT	Co-operative Tools
CWP	Controller Working Position
ERATO	En-Route Air Traffic Organiser
GHMI	Ground Human-Machine Interface
LOA	Letter Of Agreement
PAT	PHARE Advanced Tool
PC	Planning Controller
PD/3	PHARE Demonstration 3
PHARE	Programme for Harmonised ATM Research in Eurocontrol
PROSIT	PROblem SITuation
RPC	Remote Procedure Call
RPVD	Radar Plan View Display
SIA	Set of Interfering Aircraft
SID	Standard Departure procedure
STAR	STandard ARrrival procedure
TEPS	Trajectory Editor and Problem Solver
TFL	Transfer Flight Level
TC	Tactical Controller
TP	Trajectory Predictor
URD	User Requirement Document

7.2 DEFINITIONS

Interaction A couple of aircraft that may be "matter of concern" (or require additional attention) because their trajectories are too close in the view of the ATCO. The difference with a conflict is that there may be an interaction without any loss of minimum separation standards between the aircraft. This world is used within the Co-operative Tools project to speak of both conflicts (certain or possible) and cases where one aircraft is a constraint for another in case of manoeuvre (called "restricting" aircraft).

Interacting aircraft	This aircraft is in interaction with an other one.
Restricting aircraft	This aircraft may be a constraint if the ATCO decides to change the trajectory of the other aircraft.
Set of interfering aircraft (SIA)	Given a selected aircraft, its set of interfering aircraft is the list of aircraft, which are either interacting with or restricting to it.
Problem situation(PROSIT)	A subset of aircraft that can be handled as a whole by an ATCO (a PROSIT has a name).
Significant aircraft	In a PROSIT, an aircraft that is interacting with another one in a way that is directly related with the problem situation name .
Contextual aircraft	In a problem situation, an aircraft that is interacting to, at least, one of the significant aircraft.
Limit time	The time after which the resolution of the problem situation will presumably be more difficult. This time is attributed to a problem by the system (this is what we call **"time stamping"** a problem).

7.3 REFERENCES

[0] PATs Co-operative Tools User Requirements Document CENA/93.766
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[1] PATs Co-operative Tools User Requirements Document CENA/97.536
(PHARE /CENA/PATs/CET/CT/97/03)

[2] The PHARE Advanced Tools Event List
(PHARE /NLR/EL/WP0.2/97/10) [3] PD/3 Operational Scenario Document Volume II (PHARE/NLR/PD/3-1.1.3.2.2/OSD2.2.0)

[4] PD/3 IOCP Programme Human Centred Approach EXPERIMENT REPORT (PHARE/CET/PD/3-2.1.2/SSR; V1)