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National Aerospace Laboratory NLR

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Interactions
Advanced controller displays, an ATM essential

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Summary

Saturation of the Air Traffic Management (ATM) system, combined with limited opportunities to increase the capacity based on current practice, provide the economic incentive to improve ATM.

Over the years, ATM has evolved into a set of finely tuned interactions between air traffic controllers, procedures and ATM systems. The resulting controller display is defined based on extensive experience displaying a relatively limited set of radar and flightplan information.

Concurrent research at various European establishments has provided several stand-alone ATM tools, based on human-centered ATM concepts, which aim to provide the required capacity increase while maintaining or increasing current safety levels. To avoid increasing controller workload and/or error rates, attention needs to be paid to the interaction between the controller, these ATM tools and existing ATM systems.

This paper describes a large-scale multi-national exercise in which several different ATM tools from various European organisations were integrated into a tool-cluster on a real-time simulation platform. A dedicated, integrated Human Machine Interface was designed and implemented.

The expense and time consumption of such exercises demands a “first-time-right” approach. The major lesson learned from the interactions between advanced ATM tools and the controllers is that a “human-centered” approach (i.e. providing system functionalities based on the needs of the controller and the task requirements) is essential. This human-centered approach contrasts with the traditional “technology-centered” approach, which is mainly driven by the capabilities of the technology employed. The implications for ATM system development, like a shift from the waterfall model to a spiral development model, are addressed.

Contents

(26 pages in total)

1 Introduction

In a "human-centered" Air Traffic Management (ATM) paradigm, the displays which convey the traffic information to the Air Traffic Controller (ATCo) form an essential component of the total system. With the advent of various new advanced ATM tools, the ATCo can be provided with a lot of new and potentially useful information. Every developer of advanced ATM tools is acutely aware of the fact that a tool's success critically depends on its interaction with the controller and its integration with the ATM concept. As in any safety conscious industry, there is a tendency to rely on proven technology above promising, but unproven, new concepts and solutions.

Tool developers traditionally do not base their Human Machine Interface (HMI) on an underlying theory for the total task of the ATCo. Instead, HMI designs tend to be based on what can be done practically and efficiently, using the HMI of the existing target ATM system as a constraint. This approach is known as the "technology-push" or "technology-centered" approach.

The alternative to the technology-centered approach is the human-centered approach to ATM system design. The human-centered approach starts by defining the characteristics of the underlying ATM concept. Based on this, an integrated view of the task of the ATCo is developed, including his interactions with the supporting ATM tools.

The current state-of-the-art does not allow full validation of new ATM concepts without real-time simulations. These simulations involve real ATCo's using the tools in a representative environment under a realistic workload.

The innovation presented in this paper was to start with a coherent ATM concept. Subsequently a set of novel ATM tools, each of which had earned its merits in stand-alone experiments, was combined into a new integrated ATM environment. The results were evaluated using a variegated group of ATCo's, with many years of experience each, from various European countries. The evaluation used simulated high traffic density scenarios.

Section 2 contains a cursory overview of the operational ATM concept. This concept has been developed using a human-centered approach, while taking into account the capabilities of the available advanced ATM tools and capabilities to share information with the pilot using the Aeronautical Telecommunication Network (ATN).

Section 3 provides a short description of the experiment, including an excerpt of the operational evaluation of the experiment indicating its success. Sections two and three provide the information needed to fully appreciate the description of the problem encountered in the en-route case, contained in section 4. Subsequently, section 5 provides the analysis from a technical perspective, while section 6 summarises the findings in the conclusions. Details of the ATCo HMI are presented in Appendix A.

2 Operational ATM concept

The Programme for Harmonised Air Traffic Management Research in EUROCONTROL (PHARE), set up in 1989 and completed at the end of 1998, was conducted by the ATM research centers of the UK, France, Germany and the Netherlands, plus EUROCONTROL Experimental Centre (EEC). It aimed to "organise, co-ordinate and conduct studies and experiments aimed at investigating the feasibility and merits of a future air-ground integrated air traffic management system in all phases of flight" [12].

PHARE's main concept enhancements relevant to this paper were:

- integration of the air and ground systems;
- support of the pilot and the ATCo with automated tools while retaining the human in-the-loop paradigm for both the aircraft and the ground side;
- introduction of 4D-trajectory negotiation and 4D-planning in a multi-sector environment.

Implementation of these enhancements had to lead to a prototype of an ATM environment up to the task of dealing with predicted 2005-2015 traffic levels [10]. This represents a 150% increase over 1995 levels [13].

Use of 4D-planning in space and time requires more accurate navigational performance on the side of the aircraft. To share this information with the ground system, a digital communication channel (data link) has to be present. With the same high quality information becoming available to both the pilot and the ATCo, automated tools can be utilised to reduce workload and enhance situational awareness. Examples are a flight path monitor, long term conflict detection and resolution tools and arrival/departure schedulers. Although the PHARE concept allows for user preferred trajectories from Standard Instrument Departure (SID) to Standard Arrival Route (STAR), the example discussed relates only to the en-route phase. However a similar problem has been encountered in the approach phase, which further supports the conclusions.

To ensure that all these elements that gather, communicate and process information work together and can be visualised to the pilot and the ATCo in a consistent and intuitive way, a coherent, human-centered ATM concept had to be established. For PHARE, this concept was built around the use of 4D-trajectories.

Tools provide the pilot and the ATCo with a visualisation of an aircraft's trajectory and allow these users to obtain more information of and make modifications to the 4D-trajectory. Using the data link, trajectories are automatically communicated and negotiated between the ground systems and the aircraft. All advanced tools work on the basis of trajectories (e.g. the flight path monitor verifies whether actual position updates from the surveillance tool conform with the agreed 4D-trajectory).

The same integrated, human-centered approach is also used for the design of the ATCo HMI. As a result, information is combined and shown as much as possible in the familiar radar display. When information is shown in more than one window, this is done in a consistent way and selecting one instance of the representation will also highlight all other instances [5].

As a result, the ATCo HMI becomes more intuitive which reduces the learning time. Inconsistencies between different representations of the same information are avoided. More information on the PHARE operational concepts can be obtained from [10], [11], [12] and [14].

3 Experiment description

Due to the inherent complexity of ATM systems, data need to be collected and analysed to verify new ATM concepts. The amount of detail needed for a realistic assessment requires large real-time simulations to arrive at a judgement on the proposed concepts [8]. [13] even states that a full understanding of the operational concept only comes when a real-time simulation is available. This paper describes the PHARE Demonstrator 3 (PD/3) and its extension the PD/3 Continuation Trial (PD/3 CT). The findings discussed would not have been obtained in a less realistic environment, confirming the need for such costly exercises.

From an operational perspective en-route air traffic control in PD/3 required the integration of the following tools:

- trajectory predictor (TP)
- negotiation manager (NM)
- conflict probe (CP)

- problem solver (PS)
- flight path monitor (FPM)
- ground human machine interface (GHMI).

Most of these tools, with the exception of the GHMI, were developed in different locations using the technology-centered approach. The resulting tools had been integrated into the various ATM systems in local use. These ATM tools were subsequently to be integrated into a tool-federation, or “tool-cluster” in project parlance, on NLR's Air traffic control Research Simulator (NARSIM). NARSIM's client/server based architecture (called GEAR), is designed to facilitate the integration of various components, even when supplied by different organisations.

Figure 1 depicts the architecture of the resulting PD/3 simulator as used in the PD/3 CT. As can be seen in figure 1, the GHMI serves as the integration of all ATM system communication with the ATCo, that is, for the user it is the glue of the ATM system. Consequently any inconsistency in the underlying ATM tools will be detected as a problem in the GHMI module. Unexpected behaviour of the system as discussed in this paper, led to the need for the PD3/CT project.

To give an indication of the effort of executing a major real-time simulation, 25 ATCo's from 8 countries evaluated the PD/3 tool-cluster at NLR during the PD/3 CT trials. The exercise consisted of 3 measured sectors complemented by 5 feeder sectors and 3 holding areas. The simulated traffic was generated by 15 pseudo pilots “flying” up to 300 simulated aircraft complemented by real pilots flying a research aircraft. Various exercises used traffic up to twice the traffic of the busiest day of 1996.

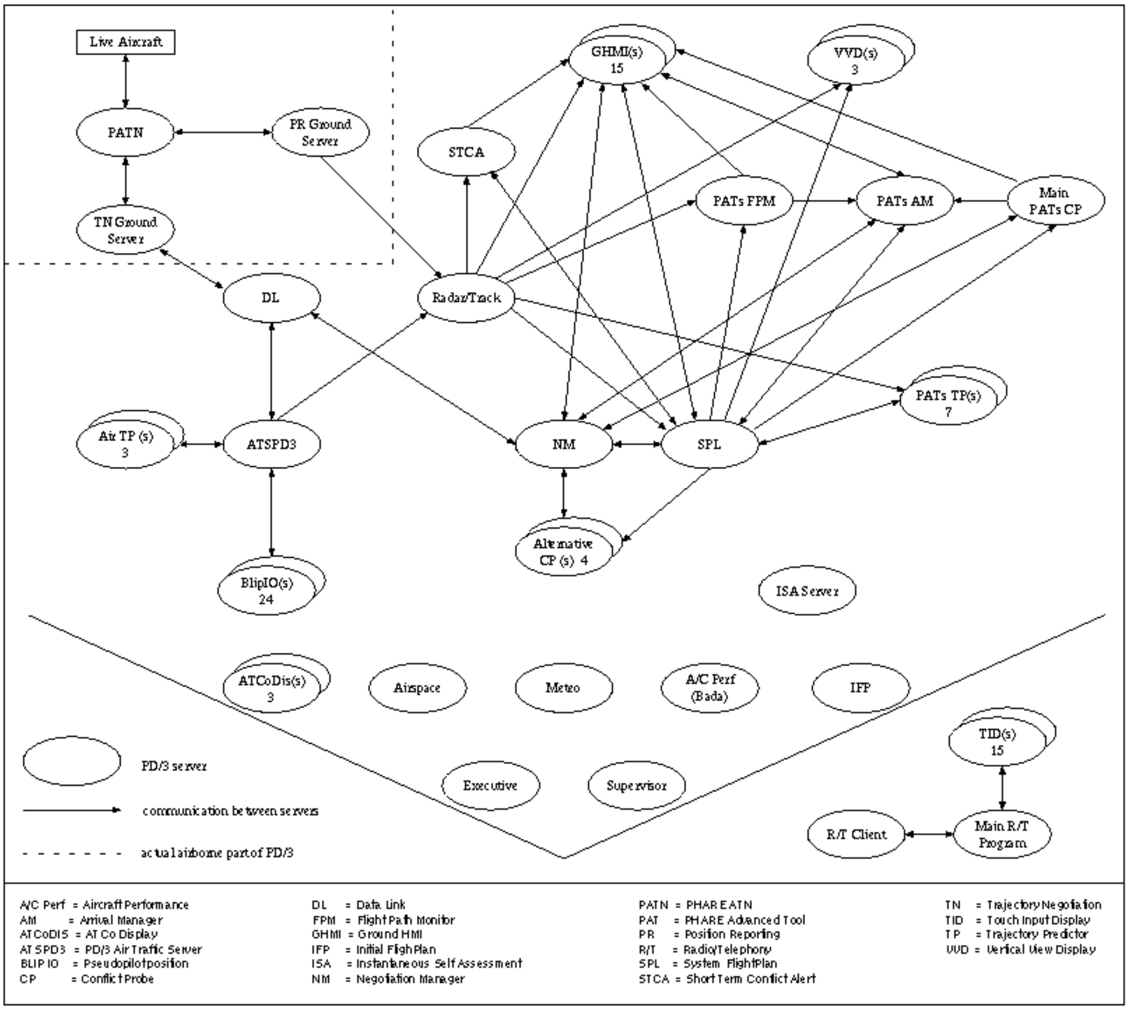

Fig. 1 PD/3 system architecture

The considerable costs as well as the deployment of scarce human resources like ATCo's required that the experiment be “first-time-right”. The mere existence of the PD/3 CT implies that in this case a second try was required. The need for this second experiment was partly caused by problems that became visible during the tool integration, an example of which is described in section four and analysed in section five.

From an operational point of view the PD/3 CT experiment was successful. During the evaluations, ATCo's mentioned feeling confident about handling the expected air traffic volumes for the period 2005-2015. More information about the results of the PD/3 CT can be obtained in [13].

4 En-route case

Based on the PHARE ATM concept described in section two, an integrated HMI has been designed. From an ATCo's point of view, this HMI integrates the Highly Interactive Problem Solver (HIPS) tool with the trajectory prediction tool. The HIPS is a stand-alone tool developed using the technology-centered approach. A dedicated HMI has been implemented and the tool has earned its merits in stand-alone simulations, that is simulations in which the HIPS is integrated into an environment akin to current ATC systems.

Similarly, the TP tool was based on an Experimental Flight Management System, which has proven its worth in many simulations. This TP was build using the technology-centered approach and integrated in NARSIM, the simulation platform used. This re-use of proven tools for combined experiments forms the core of the PHARE way of working. Its success has been documented in [4].

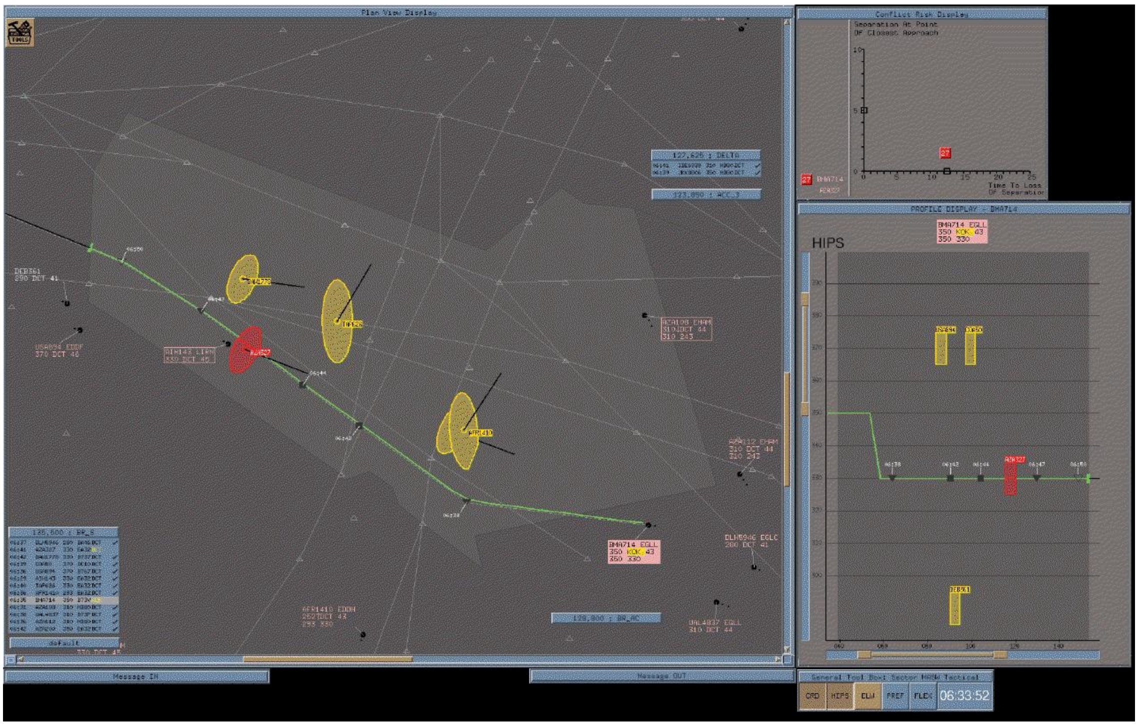

Fig. 2 Interactive ATM tool detects possible conflict

The ATM concept requires a tool that allows the ATCo to intuitively modify a 4D-trajectory and obtain real-time response to the proposed modifications. The HIPS is designed to provide this. In order to obtain the real-time response (and due to its development as a separate tool), however, the HIPS uses its own computationally efficient trajectory prediction. In the integration platform, a full accuracy trajectory prediction tool is required. This tool is needed by subsequent modules (e.g. a conflict detection tool) which require the TP's full precision. Consequently neither tool can be omitted.

To follow the human-centered design approach, the ATCo needs a consistent presentation. The design choice was to construct an HMI which shields the differences between these two autonomous tools from the ATCo. Figure 2 provides a screen of the resulting HMI. It shows that the conflict probe has detected a potential conflict, based on information from the full accuracy trajectory predictor.
For a larger image and a full description of all relevant features of this HMI please refer to appendix A.

The ATCo investigates a solution to this conflict using the intuitive interface of the HIPS to “pick” the trajectory and “drag” it outside infringement area. The real-time response of the HIPS is an essential feature for this problem solving activity. Figure 3 shows the resulting trajectory.

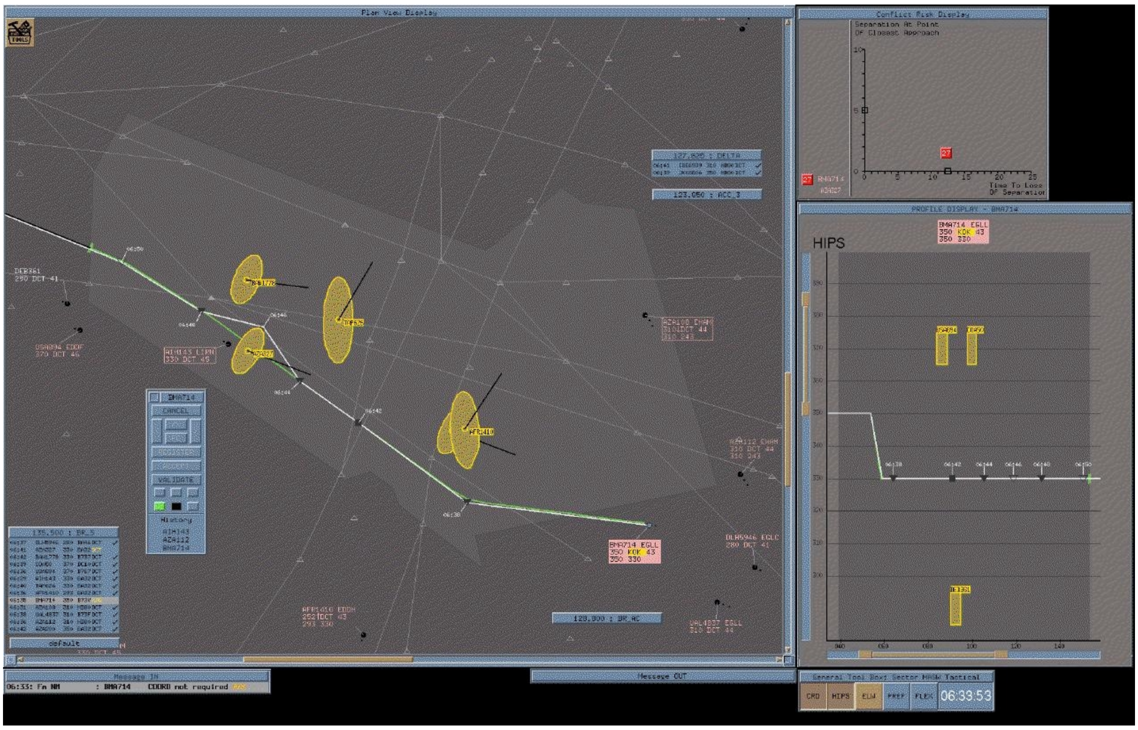

Fig. 3 Controller solves conflict with interactive tool, minimising trajectory interference

In order to minimise disturbance of the aircraft's preferred trajectory, the solution only just avoids the warning area of the infringing second aircraft. To inform the ATCo, the red areas on the Plan View Display (PVD) and the vertical view display have disappeared, however the conflict remains in the “conflict and risk display” as at this moment the modified trajectory has not yet been accepted.

After the ATCo is satisfied with a solution, it needs to be validated using the full accuracy trajectory predictor. This is accomplished by clicking on the validate button of the “trajectory support tool” sub-window.

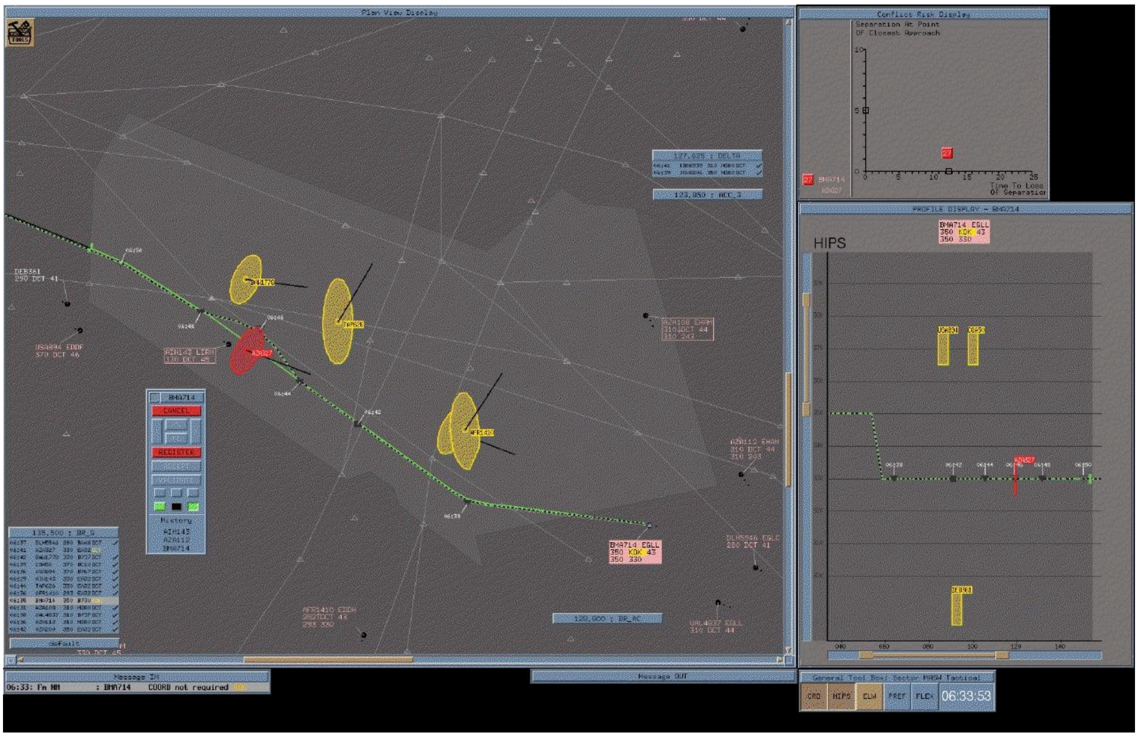

Fig. 4 Slower, full accuracy tool discards solution

As shown in figure 4, the result of the trajectory predictor's more accurate modelling of the aircraft's turn behaviour is that the conflict re-occurs. Although the resulting vertical separation infringement is significantly reduced, the solution is of course unacceptable.

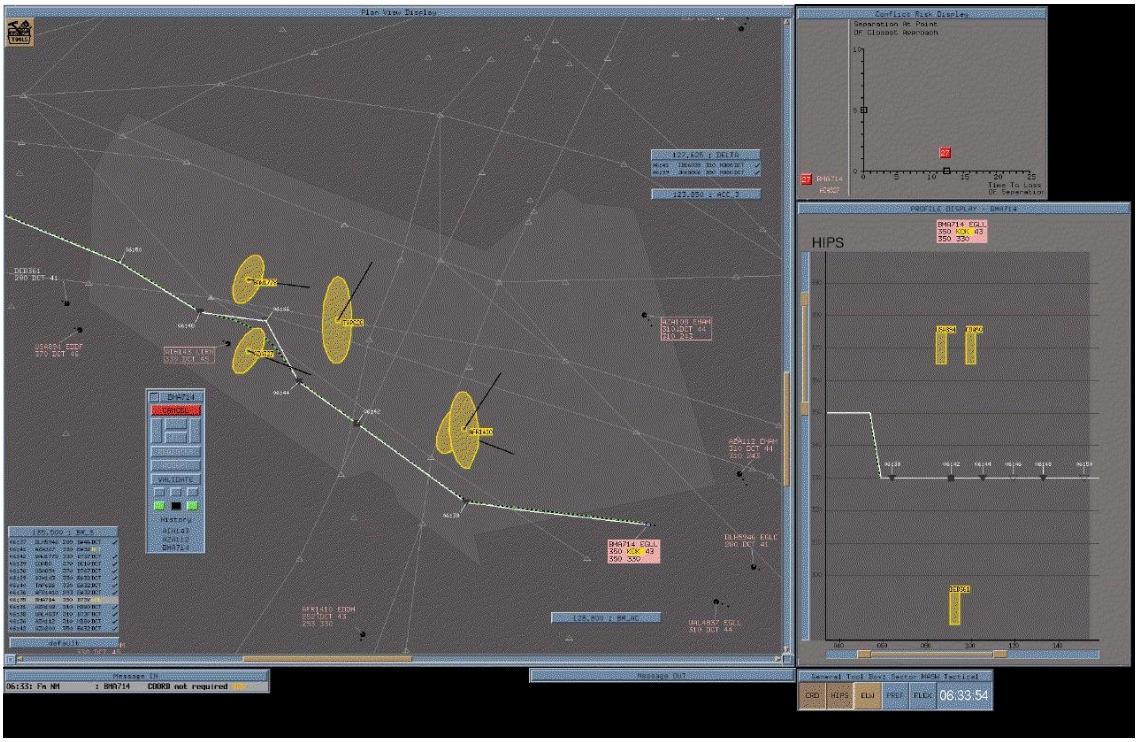

Fig. 5 Controller solves conflict again with interactive tool

Consequently the ATCo has to pay attention to this conflict again, by proposing a second solution (see figure 5). Due to the time delay involved this second problem solving action disturbs the scheduling of mental tasks by the ATCo. As such this is not a minor technical inconvenience, but a major interference with the ATCo's routine distribution of effort over his normal tasks of monitoring, controlling, checking, diagnosing and problem solving [8]. Of the HMI design guidelines of [6] (see section A.1) the “be consistent” and “minimise the use of modes” has been violated.

To conclude the example, figure 6 shows that the second solution is validated by the full accuracy trajectory prediction tool. Subsequently this solution has been sent to the pilot and acknowledged. The conflict disappears from the “conflict and risk display”. As these solutions rely on intermediate points which can not be known in advance, the human-centered approach requires the use of a digital data link to provide this information to the pilot.

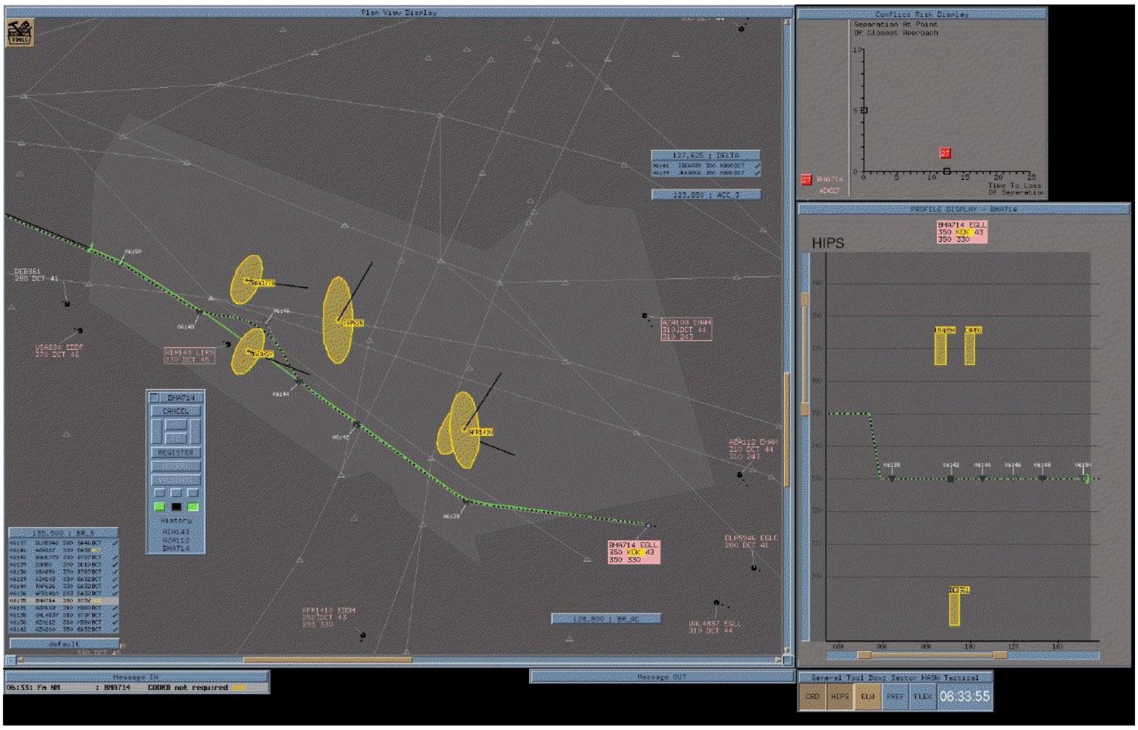

Fig. 6 Second solution confirmed by full accuracy tool

5 Case analysis

5.1 Human-centered approach

In the example provided, effort has been made to implement a human-centered solution. Both the ATM concept and the GHMI design complied with this approach and were appreciated by the ATCo's. The resulting intermittent failure of the implementation was caused by two tools. These independently developed tools were not *integrated* but merely *harmonised*. Consequently in special circumstances they behaved inconsistently. This kind of problem can be solved by extending the human-centered approach to the integration of separate tools into tool-clusters or tool-federations. Such integration comprises:

- using consistent input data. Partly, this can be accomplished by splitting a tool into separate modules and using Application Programming Interfaces (APIs) to unambiguously define the interfaces. The input processing should then be a separate module apart from the actual algorithm. A similar argument holds for splitting output processing in separate modules;
- analysing the sensitivity of the integrated tool-cluster for inaccuracies in the input data provided;
- redesigning the computationally efficient trajectory prediction tool based on a conservative approximation of the results of the full accuracy trajectory prediction tool.

In the operational evaluation the ATCo's agreed that the inconsistencies between the HIPS and the TP tool caused confusion [13]. This confirms that such issues should be dealt with prior to embarking on costly full-scale experiments.

5.2 HMI

To avoid inconsistencies in the ATCo HMI, the APIs of all components should be agreed upon as early as possible. These APIs can be used to test interactions between tools for inconsistencies and deadlocks. This approach can be extended to assess the response time of tool-clusters. Using appropriate methods, this can be done before the tools themselves are implemented. These checks reduce the number of defects that show up later in the development process, at which time resolving them is more expensive [1].

The conflict and risk display received mixed reviews, indicating that more work needs to be done on this display. Possibly this is the result of this display being technology-centered (it was easy to provide) instead of human-centered (based on what the ATCo needs to know for his task). This conclusion is supported by the development of the Activity Predictor Display within PHARE [5] as a replacement of the conflict and risk display.

The message in/out displays were not deemed relevant by the ATCo's. This illustrates Karat's [6] guideline that the HMI has to be consistent which in this case means providing information in the ATCo's preferred graphical format instead of the tabular format used.

The Sector Inbound Lists were not used frequently, again due to the presentation in a tabular format. This is especially significant as even during periods of high workload more frequent use of these lists did not occur.

5.3 System development

The previous three cases support another important finding: this experiment confirms that a waterfall based system development approach (like [3]), although convenient for system developers, is not always appropriate, because:

- some system characteristics can only be judged when a prototype is made available to the users. The waterfall model does not permit this early in the development process;
- during the system realisation phase the operational concept will mature resulting in evolving system requirements. The waterfall model assumes frozen requirements.

Consequently a spiral development model [2] is more appropriate to arrive at the final system to be used in the resource expensive real-time simulation. For other application areas the same conclusion has been reached [7].

5.4 Software metrics

To put the size of the GHMI module into perspective, information is provided in table 1 about the implementation size of various parts of the PD/3 simulation platform. All module sizes are expressed in units of thousand lines of code (KLOC) including comments. Programming languages used to implement the modules are Ada, C++ and C.

Table 1 Relative component size

Module	Description	KLOC
GHMI	PD/3 Ground HMI	221
FPM	PD/3 Flightpath Monitor	35
AM	PD/3 Arrival Manager	20
NM	PD/3 Negotiation Manager	20
ATS	Air Traffic Server	20
CP	PD/3 Conflict Probe	16
SPL	System Flightplan Server	8

The figures in table 1 support the conclusion that the ATCo HMI is an essential module in any real-time ATC simulation. Remember also that tool inconsistencies as seen from the users' perspective may only show up in the HMI. Therefore appropriate attention needs to be paid to this module during system development.

The figures also show that implementing an algorithm is only a minor part of the total process from algorithm to useful prototype.

The relative size of the GHMI module with respect to the ATCo tools and even the entire simulation platform, implies that a design based on generic display software (resulting in a smaller product specific description) can lead to a large reduction in realisation time and costs. The resulting early prototypes comply with the spiral development model. At NLR, wARP is a project aimed at implementing such generic display software [9].

6 Conclusions

To accommodate ever increasing air traffic in a human-in-the-loop ATM system, capacity needs to be extended by increasing the productivity of the ATCo's. This can be accomplished by providing them with advanced tools, which enhance their efficiency.

Advanced ATM tools are usually conceived, developed and evaluated independently, including a dedicated locally optimised HMI. The most promising tools are subsequently integrated into existing ATM environments. During this process the tool's HMI is integrated with the existing ATM system. This traditional technology-centered approach can yield unexpected inconsistencies, which may reduce any potential capacity gains. It may even lead to unjustified repudiation of the tools being evaluated.

Based on the experience described, a better way to proceed is the human-centered approach. Starting from a clear ATM concept to guide the design decisions to be made, human factors considerations should be taken into account from the start of the development process. Items to take into account during this human-centered system development process are:

- treat the ATCo HMI as an essential part of any simulation development project;
- design an HMI based on the ATCo's information needs instead of what is available and check the ATCo's reaction during actual usage;
- take HMI guidelines seriously, especially with respect to consistency and intuitive use;
- use generic modules and tools to construct complex ATCo and pilot HMIs;
- use APIs early in the system development process to check consistency and timing requirements within tool-clusters;
- use a spiral software development model instead of a waterfall model;
- use consistent or harmonised algorithms (i.e. fast response type algorithms that produce conservative estimates of the results of the full-precision tools within the same tool-cluster);
- analyse data accuracy required by various tools within the tool-cluster;
- use consistent data sets between tools.

Integration tests of tool-clusters are a necessary step between research and an industrial product. These tests are expensive and time consuming. What appear to be minor inconveniences from a technical point of view can even invalidate an entire exercise. This implies the need for a “first-time-right” approach. Unlike the traditional technology-centered approach, a human-centered approach combined with a spiral development process is essential to obtain this “first-time-right” objective.

7 Acronyms and abbreviations

4D	defining points in space and time
API	Application Programming Interface
ATCo	Air Traffic Controller
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
CP	Conflict Probe
EEC	EUROCONTROL Experimental Centre
FPM	Flight Path Monitor
GHMI	Ground Human Machine Interface
HIPS	Highly Interactive Problem Solver
HMI	Human Machine Interface
NARSIM	NLR's Air traffic control Research Simulator
NLR	National Aerospace Laboratory
NM	Negotiation Manager
KLOC	one thousand Lines Of Code
PHARE	Programme for Harmonised ATM Research in EUROCONTROL
PD/3	PHARE Demonstrator 3
PD/3 CT	PD/3 Continuation Trial
PS	Problem Solver
PVD	Plan View Display
SID	Standard Instrument Departure
STAR	Standard Arrival Route
TMA	Terminal Movement Area
TP	Trajectory Predictor
TST	Trajectory Support Tool
wARP	ATCoDis Redesign Project

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Appendix A Detailed description of the Ground HMI

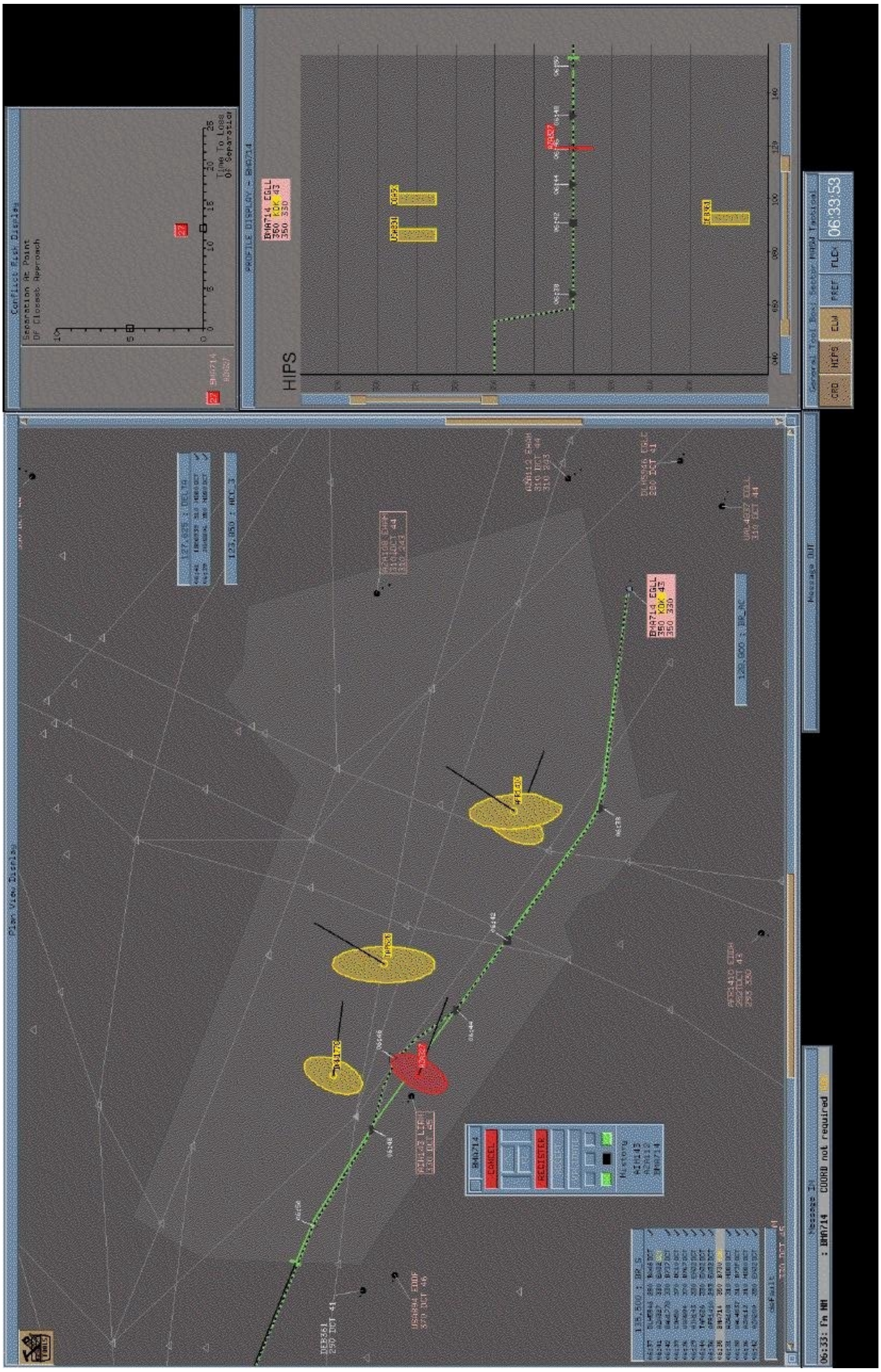

Fig. 7 Overview picture of the PHARE ATCo HMI

A.1 Design guidelines

In order to appreciate the functions and complexity of the Human Machine Interface (HMI), the HMI will be described in detail. For some features the design rationale will be provided. [6] developed the following design guidelines to ensure the usability of HMI's:

- use a simple and natural dialogue
- provide an intuitive visual layout
- speak the user's language
- be consistent
- provide feedback
- provide clearly marked exits
- provide shortcuts
- provide assistance. (This requirement is not applicable as the HMI is used by highly skilled users which have been specially trained on, amongst others, the HMI)
- allow user customisation
- minimise mode effects
- support input device continuity.

Where relevant these guidelines will be referred to in the following detailed HMI description.

A.2 General features

In figure 7 four main windows are visible. The general features applicable for each window are:

- the basic design principle is, that for characteristics which are not ATC-specific, the behaviour should be similar to PC-based windows systems. In cases where this would result in a deviation from existing ATC systems, compatibility with existing ATC systems prevailed. In this way the ATCo's expectations can be met and the learning effort reduced in accordance with the first three design guidelines. This choice is fine for an experiment. In an operational system the conversion training might be less of a problem, however the fast evolution of commercial window systems might result in a need to regularly update the available HMI to the new features of commercial windows systems;
- a standard use of the window decorations:
  - each window is labelled with an identification inside the upper window border;
  - each window can be re-sized using the familiar dragging of the border. In regular windows applications changing the window size sometimes results in a different scale and sometimes does not. To avoid such inconsistencies, the actual radar display has two extra controls, which allow window resizing with constant scale and constant area respectively.

- for those windows which display an area ("PLAN VIEW DISPLAY" and "PROFILE DISPLAY BMA714"), the slide bars can be used to select the display area. The size of the slide bar indicates the relative size of the displayed area with respect to the total area available;
- the colours, font size, and default availability, size and position of each window can be saved. Up to ten preferred configurations can be stored in accordance with the customisation guideline;
- a window may contain sub-windows. The sub-windows can be positioned inside or outside the corresponding window.

A.3 Plan View Display

The major window is labelled "PLAN VIEW DISPLAY". This window provides all information which is currently available in traditional ATC systems. The major features are:

- the active sector (Belgium Upper Airspace) is depicted in a lighter shade of the background colour;
- in order to be intuitive, the window mimics a conventional radar display for the standard features;
- only flights which satisfy the filtering rules are displayed. Note that these rules are context specific; when a trajectory is edited using the HIPS (Highly Interactive Problem Solver), all flights not involved with this trajectory are automatically made invisible;
- minimal label information is provided. On request extended labels can be provided. Label colours are used consistently to provide status information on the flight. Labels of aircraft in need of an ATCo action are boxed;
- the selected trajectory is shown in green. Only this trajectory can be modified by the ATCo. The label will be highlighted and expanded into a full label;
- a yellow area depicts a warning (another aircraft is close but will not infringe the separation criteria);
- a red area depicts a conflict (another aircraft is predicted to infringe the separation criteria);
- the "ACC-3" and "BR_AC" sub-windows list all aircraft which will enter the active sector from the ACC-3 or BR_AC sector respectively. The "DEFAULT" sub-window collects all remaining aircraft. The border above these sub-windows provides the radio frequency of the corresponding sector;
- the "Message IN" sub-window lists the status of the incoming messages for the ATCo. For consistency one area is used for system messages, messages from adjacent centers and downlink messages from the aircraft;
- the "Message OUT" sub-window lists the status of all outgoing messages from the ATCo. This list is empty in figure 7;

- the selected trajectory can be modified interactively by picking any point on the trajectory and dragging it to the desired position. In order to provide an intuitive interface, the trajectory and the displayed conflicts and warnings will change immediately. This requirement imposes real-time requirements on the underlying trajectory prediction and conflict detection algorithms.

A.4 Profile Display

The “PROFILE DISPLAY - BMA714” (figure 8) provides a vertical view of the selected flight. The major features are:

- the vertical scale with flight level information;
- the horizontal scale with distance information in nautical miles;
- for consistency the selected trajectory is shown in the same colour as on the Plan View Display;
- different display filtering rules apply for the zones in the horizontal and vertical views;
- the full label of the selected aircraft is highlighted and displayed on top of the display;
- a yellow area indicates a vertical warning. Note that these yellow areas relate to other flights than the yellow areas in the PVD;
- a red area indicates a conflict. Note that this conflict is the same as the one shown in the PVD.
  A conflict only exists when both the horizontal and vertical separation criteria are predicted to be infringed;
- the selected trajectory can be modified interactively by picking any point on the trajectory and dragging it to the desired position. The same real-time algorithms are used as in the PVD.

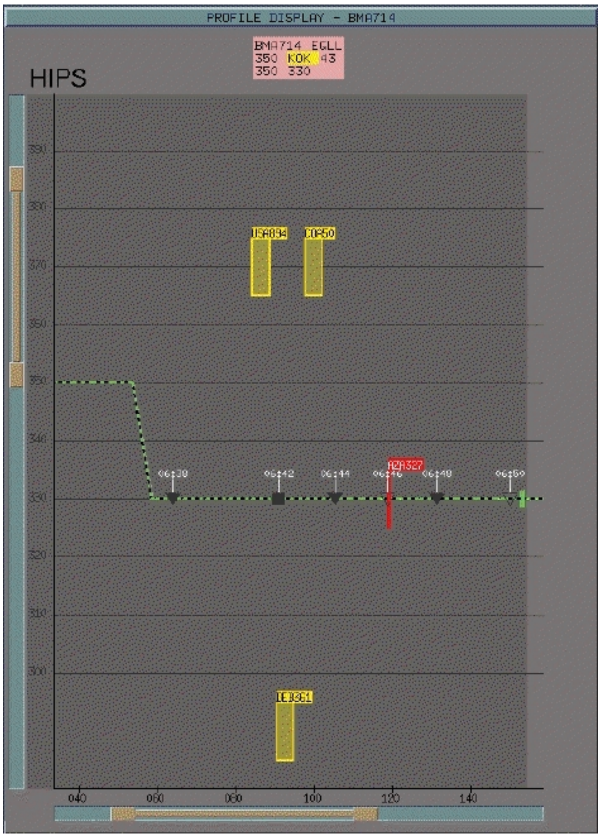

Fig. 8 Profile Display

A.5 Conflict and Risk Display

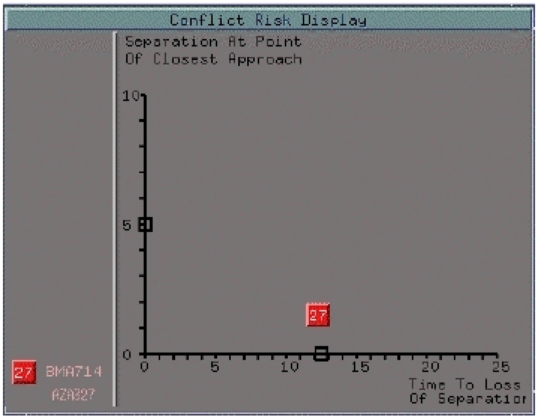

Fig. 9 Conflict and Risk Display

The “Conflict and Risk Display” (figure 9) provides a severity indication for all conflicts. The vertical axis provides the “separation at point of closest approach” in nautical miles, the horizontal axis provides the “time to loss of separation” in minutes. The black boxes are used to scale each axis. On the left the callsigns of each conflicting aircraft pair are provided.

Note that for an operational display the annotation at the axis would be omitted to improve picture clarity.

A.6 General Toolbox

Fig. 10 General toolboy

The final window, labelled “(figure 10) General Tool Box: Sector MSAW Tactical” provides information on the selected display configuration. The buttons are:

- “CRD” for the “Conflict and Risk Display”, which is selected in this example;
- “HIPS” for the HIPS display, which is selected;
- “ELW” for Extended Label Window, which is not selected;
- “PREF” to store or retrieve the preferences for up to ten display configuration settings;
- “FLEX” for flexibility. This button is intended for developers only. It allows changes to even more characteristics of the display, like the fonts used;
- the time of the simulation in the familiar hours:minutes:seconds format.

A.7 TST sub-window

In case the selected trajectory is modified the HIPS tool will provide feedback in real-time. The special TST (Trajectory Support Tool) sub-window appears automatically to provide the necessary feedback. It is labelled with the flight's callsign ("BMA714", in figure 11). For consistency adjacent sectors and aircraft are treated in the same way.

The function of the buttons is (describing the buttons from the top downwards):

- "cancel" will remove any modification
- the three buttons labelled with a left, upward and right pointing arrow are used to start the trajectory negotiation with the upstream sector, aircraft and downstream sector respectively. The button labelled FC is used to deliver a Formalised Clearance to the aircraft;
- "register" will set the modified and validated trajectory to the active trajectory;
- "accept" will accept a proposal from either an adjacent center or an aircraft. Note that a proposed trajectory can only be rejected by submitting a counter proposal;
- "validate" will validate the trajectory by using the full precision trajectory prediction tool. Due to its higher accuracy the trajectory predictor can not calculate trajectories fast enough for interactive use;

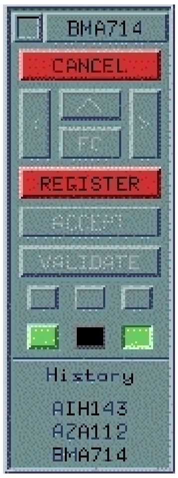

Fig. 11 Trajectory Support Tool

- the top row of the six colour buttons displays the status of an incoming trajectory from the adjacent sectors, an incoming trajectory from a pilot and an outgoing trajectory to an adjacent sector respectively;
- the bottom three colour buttons are used to recall the current, the original and the working trajectory. To ensure consistency the same colour coding is used as for the trajectory on the PVD and the profile display;
- the "history" section shows the last few other flights of which the trajectories were modified.