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INTEGRATING FMS DATA INTO AIR TRAFFIC CONTROL

A PROTOTYPING EXERCISE EXPLORING THE OPERATIONAL CONSEQUENCES AND POSSIBLE EFFECTS ON CONTROLLER ROLES.

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Abstract :

This note describes a prototyping exercise that investigated the possibilities for integrating FMS generated data into operational ATC using datalink as the communications channel. The assumption was that the use of such technology should support an increase in the capacity of the ATC System.

The study concentrated on the behavioural aspects of how controllers might interact with various emerging technologies as they execute their control task. The objective was to explore the operational procedures needed to handle FMS data in real-time and to understand the possible effects on the role of the Controller. It was hoped that this process, which excluded formal capacity, cost-benefit or safety analysis, would allow clear identification of key questions which could be used to contribute to other more formal research programmes.

AS09 SUMMARY.

AS09 was a system prototyping exercise which took place during 1994 and early 1995 at the Eurocontrol Experimental Centre Brétigny, France, contributing to the European Air Traffic Management System Research and Development programme. The project used approximately two and a half man years of effort.

The study assumed that integrating 4-D FMS generated data into real-time ATC, through the use of datalink communications, could increase airspace capacity in a radar environment.

Its main objectives were to define and investigate a scenario based on this assumption and thus

- evaluate what the operational constraints of such a system could be, and,
- to understand the possible controller roles which could result from the implementation of these technologies.

Operational controllers from Maastricht Centre were involved in the prototyping exercise and provided an invaluable user viewpoint. Prototyping, involving users early in the design process, was shown to be a very powerful tool for refining ideas.

This study concentrated on identifying questions and many are posed within the body of the Note. The project provided a sound basis for clarifying ideas and identifying areas for future work of a more objective nature.

The main conclusions can be summarised as follows:

- If 4-D FMS Data is used to create a pre-planned environment based on radar type separation standards and with planner sectors boundaries existing all the way down to the functional layer of the system then the behaviour of Executive Controllers and Pilots will be more constrained than at present. The system will be less responsive to short notice requests than present systems which indicates the need to anticipate requests wherever possible at the planning level.

- The experiments, based on a simplified sector with simplified procedures, allowed the Planner controller to manage a throughput approximately three times higher than the current maximum (achieved by doubling traffic levels and increasing sector size). This represented an increase of approximately 70% on the airspace throughput. The indications are that there is a potential for a large increase in throughput. This potential is dependant on the results of further research on human factors, cost-benefit and safety issues.

- With increased traffic levels and complexity it became extremely difficult for the Executive controller to intervene and maintain safety, when necessary, in real-time.

- It was demonstrated that if controllers tasks are concentrated on making decisions to resolve exceptions (e.g. conflicts) then the controllers will tend to become remote from the role of being in overall control of the sector. It is thus probable that by isolating the decision making tasks, as in

'Control by exception', that the role of being in overall control will pass to the system.

- The graphical tools and the general organisation performed equally well in the direct routes ('free flight') scenario as in the normal ATC route scenario.

This prototyping exercise was an investigation into the possible operational procedures required to integrate 4-D FMS data into real-time ATC. The study can be effectively summarised by answering two direct questions.

What is the possible value of integrating 4-D FMS data?

The evidence of the exercise is that the integration of 4-D FMS data could provide the potential for a probably large increase in airspace throughput but with three important qualifiers:

- The study was limited to the upper airspace,
- A more complete scenario is required to assess the practicality and safety issues of the system, and,
- There was no formal capacity or cost-benefit analysis performed.

What are the possible effects on the role of the Controller?

The effect of integrating 4-D FMS data on the role of the controller is likely to be very large. The increased amounts of very accurate data attached to each aircraft combined with a more random traffic pattern of direct routes will demand a high level of system support to manage it. This, in turn, will mean that the controller loses flexibility to handle the unexpected. The role of the controller will thus tend to become either system driven (i.e. re-active instead of pro-active) or a system supervisor. This aspect needs human factors studies to determine the most acceptable paths for development

Recommendations

The recommendations are targeted at improving the way that ATC Systems development is researched.

The Study Process

1. A realistic simulation platform is needed to allow full, objective analysis of the impact of new technologies and computer assistance on the capacity and safety of the resultant system.

2. Cost-effectiveness, capacity and safety issues must be addressed as early as possible when exploring system developments.

The role of the Controller

3. More objective-research is urgently needed to qualify and quantify the effect of increasing levels of automation on the role of the controller. Special reference should be made to understanding the effect on controllers mental modelling of 'prompts', abstract displays and graphical tools.

CONTENTS

APPENDICES

GLOSSARY

4-D FMS	Four dimensional Flight Management System (Latitude, Longitude, Altitude, Time)
AFL	Actual Flight Level
CFL	Cleared Flight Level
DED	Directorate EATCHIP Development
EATMS	European Air Traffic Management System
EEC	Eurocontrol Experimental Centre
HMI	Human Machine Interface
HIPS	Highly Interactive Problem Solver
LB	Left mouse Button
MTCA	Medium Term Conflict Alert
ODID	Operational Display and Input Device
PHARE	Programme for Harmonised Air Traffic Management Research in Eurocontrol
RNAV	Area Navigation
R/T	Radio Telephony
SID	Standard Instrument Departure
STAR	Standard Arrival Route
STCA	Short Term Conflict Alert
SYSCO	System Supported Co-ordination
TACAN	Tactical Air Navigation (route)
XFL	Exit Flight Level

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Initial study of the executive controller and ‘problem-free’ groups. A.Drew, N.Makins EEC Note No. 31/1994 (Task AS09).

Air Traffic Control System-supported co-ordination. SYSCO. Concept and functional description. Ver.1 Dec.1992.

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PART 1: THE BACKGROUND TO AS09

1. INTRODUCTION

AS09 is the task code of a program of studies and small scale prototyping exercises, undertaken at the EEC Brétigny, contributing to the European Air Traffic Management System (EATMS) Research and Development programme.

The study described in this document is a follow up to an initial exercise carried out in 1993, under the same code, and documented in EEC Note No. 31/1994.

2. SCOPE OF DOCUMENT.

This note reports the results of work executed at the Eurocontrol Experimental Centre during 1994 and the early part of 1995.

The main document is in four parts. An Appendix gives a more detailed explanation of some of the ATC functions.

Part I describes the background to the study.

Part II describes the AS09 scenario that was developed within the initial prototyping exercise and controller displays developed to support it (Phase 1 of the project).

Part III describes the exercise and evaluation of the scenario (Phase 2 of the project).

Part IV contains the observations, conclusions and recommendations.

3. OBJECTIVES OF AS09

The study was primarily concerned with developing and evaluating initial concepts. The product of this exercise was an ATC scenario which supported analysis of a mainly subjective nature. At the highest level an objective of the Study Team was to use this scenario to identify the key questions that need to be answered to ensure safe, efficient, effective systems design. It was felt by the Study Team that much ATC Systems development and research is not identifying these key issues. Many questions are therefore posed throughout the body of the Note which are not necessarily answered but will hopefully contribute in exposing these 'key issues'.

3.1 Main objectives.

The study was based on the general assumption that integrating 4-D FMS generated data into real-time ATC through the use of datalink communications could increase airspace capacity.

The objectives, based on this assumption, were to define and investigate a scenario which allowed:

- an evaluation of what the operational constraints of such a concept could be and,
- an investigation of the possible controller roles which could result from the implementation of these technologies.

The project was expected to provide a sound basis for identifying areas for future work of a more objective nature.

3.2 Secondary objective.

In order to complete the project a reasonable amount of the underlying ATC functionality had to be developed along with a functional Human Machine Interface for the controller. A secondary objective was therefore to understand the HMI requirements of the various controller roles.

4. THE PROJECT STRUCTURE.

The study method consisted of two phases:

- Phase 1: definition of the scenario and production of the software for the HMI and ATC functionality required to support it. This was performed in an iterative manner. The work was regularly reviewed by the project team, supplemented by occasional 'review weeks' when EEC controllers and other experts were asked to assess the scenario and supporting HMI.

  This phase took approximately one year. The scenario and software to support it were produced by a team of three people providing various types of expertise.

- Phase 2: refinement of the scenario, HMI and ATC functions where an operational controller from Maastricht was added to the team. This phase ended in March 1995 with a one week period of exercises and review involving two controllers from the Maastricht centre. A large part of the comments presented in this report comes from discussions and feedback during this week.

  This phase took approximately three months.

The work for both phases was based around the EEC Rapid Prototyping platform.

5. THE NEED FOR CHANGE IN ATC

The ATM system over continental Europe becomes saturated during the peak periods, mainly during the summer months and often for prolonged periods. Flow control is required to protect the integrity of the ATM system, sometimes having severe delay effects on the airlines as a consequence. Current forecasts of growth in air traffic movements are predicting annual increases in the region of 5% The problem for ATC is understanding how to both improve the current capacity and also accommodate this level of future growth. This must be achieved whilst maintaining and preferably improving safety standards.

A widely held view is that ATM system capacity can be increased through the exploitation of various factors which are influencing ATC developments. Some of these are:

- Route structures are becoming less rigid, especially at the higher flight levels.

- Both 'Free flight' and RNAV routes make it more difficult for radar controllers to identify conflict points because of the more dispersed nature of traffic patterns.
- Computer based aids and automated procedures are gradually being developed for operational use, intended as support in managing the sector.

- New technologies such as 4-D FMS, Satellite Navigation and Datalink communications are becoming available providing more data to be processed.

Together these factors have the potential of providing the ATC ground system with more accurate data on an aircraft's performance capabilities, its intended route, its intended profile and the times it will pass points along that route.

AS09 concentrated on understanding the effects of integrating these various procedures and technology. It was specifically centred on the use and integration of the data generated by aircraft 4-D FMS.

The specific aspects addressed can be described as:

- How can the information on the aircraft's future trajectory[1] be fed into the ground part of the ATC system, and

- How can it be used to increase the capacity of the system?

In particular can the Planner use this data efficiently to allow increased sector loading by reducing the number of predicted conflicts that the Executive has to resolve within the sector?

6. RESUME OF THE PREVIOUS WORK: AS09

The first exercises in the AS09 programme were conducted in August and October 1993 looking at the problem of Executive workload and how this could be reduced by creating and identifying a large group of 'Problem-Free 'aircraft, conflict-free within itself and which assumed that a Planner had established 4-D contracts with these aircraft.

The exercises were designed to gather essentially subjective feedback on some initial ideas as a first step to defining a more comprehensive scenario. Two particular aims were:

[1] trajectory - the flight plan of the aircraft described as a series of 4-D constraint points. The aircraft flies from one to the next in the most direct way, this may or may not be an ATC route. Each point is described in Latitude, Longitude, Altitude and Time.

- to identify what type of problems concerning interface requirements and sector management this segregation of the traffic into two populations would pose to the Executive, and

- to identify what type of knowledge or information on aircraft performance would be required by the Executive in this scenario where, because of higher sector loading, individual trajectories need to be tightly adhered to.

The main conclusions from this first exercise can be summarised as follows:

- Display and segregation of two populations of traffic is only one aspect of a much broader problem: a 'Conflict or Problem-Free' group ('Not-Concerned' group) is a dynamic concept which requires different methods of control and system support to be developed.

- Identification of conflicts between populations was very difficult and required more system support. The use of two colours to distinguish the two groups can lead to problems of identifying potential problems between them.

- As the proportion of aircraft requiring intervention increased Executive workload increased more rapidly. The controller was felt to be in an exposed position and not fully in control of the situation (a need for system support).

- Heavy volumes of traffic meant that the interactive label concept became a problem. Access to sensitive fields becomes almost impossible with the volumes of traffic experienced in the test (up to twice today's level). Work is needed in this field, particular if this method is to be used for inputting datalink commands.

- Direct tracks with 2 populations was almost impossible to manage because of the difficulty in identifying free airspace.

- It was not sufficient to evaluate the concept on existing airspace organisation; such ideas probably require a complete rethink on airspace structure.

7. THE CLIENT REQUEST FOR AS09

Following on from the early AS09 work Eurocontrol Division DED1 in Brussels issued a Client Request for further work. This sought clarification in the following areas:

- Is it possible to create and maintain a conflict free group of aircraft?

  - The Executive workload, can this be reduced by creating and identifying a large group of 'conflict-free'[2] aircraft?
  - The role of the Planner in preparing the 'conflict-free' group of aircraft.

2 Note: The term 'conflict-free' was later modified to 'Not-Concerned' meaning traffic which, in principle, needed no Executive intervention.

- The division of responsibility between Executive and Planner.

- The use of Datalink to provide instructions for the different phases of flight.

- The shape of the Planner and Executive sectors to allow best utilisation of airspace and allow flexibility in reducing/increasing sector volumes to allow for peaks and troughs in traffic demands.

A project was therefore set up to investigates these areas. It was decided that the operational concept would be evaluated by focusing on the following three areas:

- The use of 4D FMS data in operational ATC,
- The role of the controller in 'system supported' scenarios and
- The effect on current day procedures.

PART II: THE STUDY PHASE I
THE PROTOTYPING OF THE SCENARIO AND DISPLAYS,

8. SCENARIO OVERVIEW.

The scenario under evaluation has been developed with the aim of reducing as much as possible Executive workload per aircraft. To achieve this the Planner role is enhanced to both plan and issue ‘conflict-free' clearances for all datalink equipped aircraft passing through two, or more, executive sectors. The job becomes one of creating a large 'Not-Concerned ' group for the Executive by establishing a plan for how each aircraft will transit a sector. The individual aircraft’s plan would be communicated directly to those aircraft equipped with datalink. A negotiation process between the pilot and the controller, via the datalink, was also considered but not implemented.

The Executive still has the responsibility for the safe conduct for flights in the sector and issues traditional clearances over R/T as today. The Executive is presented with a large 'Not-Concerned' group, prepared by the Planner, for which R/T contact will not normally take place (although it is expected that these aircraft will maintain a listening watch) and for which, in principle, no action is needed. The Executive task is to act on the remaining ('Concerned') group as required.

The scenario was developed on Maastricht Upper airspace, specifically the Ruhr sector at flight level 245 and above. This was chosen because the traffic patterns tend to be more stable at the upper levels and would therefore be less complex than the Terminal areas of lower airspace. More constraints could thus be added as the scenario developed and matured.

9. THE ROLE OF TECHNOLOGY IN DETERMINING THE SCENARIO.

The role of FMS and datalink is central in this scenario. FMS technology will ensure flight path conformity and datalink will be the enabling technology whereby data can be downlinked to the ground and advanced 4-D clearances (describing a trajectory by a series of 4-D constraint points) can be issued to the aircraft.

The introduction of FMS generated data (trajectories) and datalink into ATC when viewed in the light of the more dispersed and random traffic patterns that are evolving means that assistance must be provided in detecting conflict points. The traditional sector organisation of routes allows controllers to concentrate on certain known conflict points, normally where routes cross. This stability of sector organisation is slowly disappearing with direct routing. The trajectory data could aid in this prediction of aircraft to aircraft conflicts. This was therefore accepted as the starting point of the AS09 scenario.

The question then became one of identifying who (i.e. which control position), is provided with the conflict details, what is done with that information and when.

The main possibilities identified were:

1. solutions are determined and implemented immediately, or,
2. solutions are formulated but action deferred, or,
3. data is used simply to predict future situations.

A choice was made at the start of the project as to which of the above base scenarios seemed the most reasonable to adopt.

Scenario 3 was eliminated on the basis that there is little reason to predict future situations unless some action is taken. It is true that sectors could be opened and closed on the basis of this information, but it is difficult to imagine a concept where sectors are opened and closed dynamically in response to individual conflict information.

Scenario 2 was eliminated because actions based on predicted events may not be appropriate if stored until the event. There needs to be some communication process between the parties involved which attempts to ensure that predicted events actually occur or do not occur if undesirable.

Thus AS09 concentrated on scenario 1, that is that the data is used to predict conflicts 20 minutes in advance and solutions were determined and implemented immediately, with an agreement between the pilot and the Planner on the actions needed to resolve the conflict.

10. EXAMINING THE CONTROLLER ROLES

Having determined the use of the data (i.e. conflicts would be detected and resolved in advance) the scope of the controllers responsibility and influence needed examination.

Traditionally Planners take a ‘one shot’ view at an aircraft’s plan transiting a sector. This is taken at the time that entry conditions are received from the previous sector. Any conflicts are examined and entry conditions are reviewed to see if a change would resolve the conflict. Once the Planner has checked the plan that, effectively, is the end of the Planner’s influence over the aircraft plan. Could the FMS generated data be used more effectively than this ‘one shot’ approach?

AS09 set out to test if it was possible that the majority of conflicts predicted to occur within a sector could be resolved by the Planner. The demands on the Executive for conflict detection and resolution for a given traffic level could be reduced as a consequence. This reduction in workload, combined with the support of colour and graphical displays, should allow sector throughput to be increased.

10.1 The Planner Controller role

The general assumption, in AS09, was that the Planner would have more accurate information (downlinked from the aircraft) concerning their expected trajectories through the sector. This would be available, but not necessarily presented to the controller, from a time approximately 20 minutes before the aircraft enters the sector. This information on the intentions of the aircraft would be used to perform a computer based conflict search the results of which would be presented to the Planner.

The Planner would be provided access to the details of the predicted conflicts and by using computer assisted, graphical displays, could examine these details, formulate a solution, (which would involve modifying the trajectories of one or more aircraft), and then communicate the modified trajectory directly to the concerned aircraft by datalink.

The main tasks of the Planner would be,

- **Conflict resolution**
  (see Appendix A for full description.)
  to resolve all conflicts detected by the MTCA occurring within the planner sector for datalink equipped aircraft,

- **agreeing trajectories with pilots**
  (see Appendix B for full description.)
  To communicate to the pilot, using Datalink, the necessary modifications or restrictions to the aircraft's trajectory to avoid the system detected conflicts,

- **intervening where system supported co-ordination (SYSCO) has stopped**
  (see Appendix C for full description of AUTOMATED INTER-SECTOR CO-ORDINATION PROCEDURE.)
  To complete sector entry and exit co-ordination where conflicts are involved in the process. (NB: The inter-sector co-ordination process was based on the SYSCO Concept. The objective was to make inter-sector co-ordination automatic with no involvement from the Planner unless a conflict is detected near to the boundary).

Once a boundary co-ordination process has been completed the strategy employed within AS09 is to transfer to the receiving sectors Planner the authority to modify the trajectory ('edit-rights') and communicate this trajectory as a clearance by datalink to the aircraft. The constraint is that any new clearance does not modify the aircraft's trajectory until it has crossed the boundary into the Planner's own sector.

All of these tasks must be completed and the pilot and Executive informed of the situation at least ten minutes before the aircraft reaches the point where a modification to a trajectory takes effect. Modifications can only be made to a trajectory when the Planner holds 'edit rights', that is between the time that entry conditions have been agreed until the time that exit conditions are agreed.

This is quite a dramatic change to the responsibility of the Planner. The AS09 Planner would have the ability to agree route and level changes with a pilot which will be executed without any intervention by the Executive. The clearance to climb or descend is implicit when the trajectory is agreed.

10.2 The Executive controller role

The Executive will be responsible for the safe and efficient management of the executive sector in real-time. There is no change to current practise in the case of ultimate authority and responsibility. However the new scenario involving more direct routes and datalink communications along with the enhanced role of the Planner will mean that there are several significant differences in the way that the Executive will be expected to behave.

The major influencing factor on the role of the Executive is that datalink equipped aircraft will climb and descend in accordance with their agreed trajectories without further clearance being issued by the Executive. Full information will be provided through the aircraft radar label before the event occurs. (see Appendix D on Label Functionality). This point caused much discussion later in the review week.

The principal new features in the Executive role are the following:

- **Not-concerned/concerned groups**
  a large 'Not-Concerned' group will exist for which there will not normally be R/T contact nor any action required. The Executive will normally intervene on the aircraft which are not in this group, i.e. the ‘concerned group’,

- **Constraints on his action**
  The Executive, while having the freedom to act as necessary on any aircraft, should normally work in a way that maintains the plans defined by the Planner ,

- **Updating of the system**
  The Executive will have to ensure that the system is kept updated with any tactical clearances that he has issued.

This organisation allows the traffic to be divided into two populations of aircraft; 'Not-concerned' and 'Concerned'. In general the Executive only acts on those aircraft in the 'Concerned' group. Aircraft are classified as 'Concerned' for a number of reasons:

- The aircraft is non-datalink equipped and therefore depends on Executive tactical clearances,

- The Planner has decided to leave a conflict to be resolved at the Executive level,

- The system detects a deviation between the radar data and the trajectory the aircraft has been cleared to follow (Track deviation), the aircraft is therefore off-plan,

- A Short Term Conflict Alert (STCA) which would indicate that one of the other levels of system support has failed.

Because the overall concept depends on aircraft following closely the assigned or cleared trajectory the Executive has a new constraint on the way that he operates. Traditionally the Executive has to observe boundary constraints, i.e. the aircraft have to exit the sector at a pre-arranged point, time and level, with a small degree of freedom around those conditions plus the possibility of a quick phone call to co-ordinate 'radar to radar' if the conditions cannot be met. What happens within the sector is effectively a 'black box' to everyone else.

However, the AS09 concept is based on the exploitation of the data on aircraft’s' intentions, i.e. their trajectories. The trajectories need to be followed relatively closely if the Medium Term Conflict Alert (MTCA) is to function with enough accuracy to enable the Planner to resolve conflicts. This does not mean that the Executive cannot manoeuvre aircraft, but that new, unpredicted conflicts may be created which, with increased sector complexity, could be difficult to identify.

The Executive should therefore try to get the aircraft back to its trajectory as soon as practicable in order to protect the quality of the trajectory data being used by the Planner in the MTCA. If the Executive cannot get the aircraft back to its original trajectory the system needs an updated trajectory in order to provide MTCA protection.

There is therefore one additional task for the Executive to perform: to maintain the conditions of the trajectory or to inform the system that an update is required. For this the Executive needs more support from his displays to contain the complexity at a level he can understand. More importantly, the Executive's 'black-box' control of the sector is no longer possible - the system and the Planner must be kept informed at all times as to what is happening in order to continue to plan further ahead.

11. A FUNCTIONAL DESCRIPTION OF THE SCENARIO.

The following describes how the Planner and Executive could work under the concept described above. It should be noted that the method of working is heavily influenced by the facilities and interface developed and so what follows must be considered as one among a number of possibilities.

It is assumed that the Planner sits close to the one (or more) Executives who are responsible for the same area of airspace but at the tactical level. They can, if necessary, talk to each other. Each controller has the possibility to set up the screen to a preferred configuration. In particular the controllers have the choice of whether or not to display the traffic population in two groups ('Concerned and 'Not-concerned'). The display effect is to present the 'Not-Concerned' aircraft with reduced labels. This helped to reduce severe label clutter (see Appendix D on label design).

The complexity and volume of the traffic means that a visual search for potential conflicts is not possible and the Planner is more dependent on the Medium Term Conflict Alert for identifying conflicts between aircraft pairs.

The MTCA operates 'behind the scenes'. Any conflict is made apparent to the Planner through the Conflict display (for full description see Appendix B). Using the symbols from this display as triggers the Planner can display, in the radar window, the predicted trajectories of the two (or occasionally more) aircraft involved in the conflict. A decision is then required to either:

- resolve the conflict by issuing a new trajectory to one (or both) of the aircraft involved, (if one or both are datalink equipped), or
- leave the conflict for the Executive to resolve.

Non-datalink equipped aircraft are considered to be under exclusive Executive control.

If the controller chooses to resolve the conflict it is necessary to modify one or more aircraft's trajectories. This is achieved by selecting individual aircraft and displaying their trajectory in a graphical trajectory editor tool, (The HIPS; Highly Interactive Problem Solver). Using HIPS a new trajectory is constructed for each aircraft chosen which is then communicated directly to the aircraft. This new trajectory could be modified in either the vertical or horizontal planes or both.

The functionality and use of the HIPS is a subject outside the scope of this report. (see PHARE Highly Interactive Problem Solver EEC Report 273/94 for full description). The essential point for the purposes of the study was that by using HIPS the Planner is able to identify conflict-free paths to issue to the aircraft and that having done so can assume that the aircraft will follow the new cleared trajectory.

Within this scenario the Executive, if everything goes according to plan, has little to do. Working with the 'Concerned' filter selected, only non-datalink equipped aircraft and aircraft requiring intervention (MTCA alerts left to him by the Planner, track deviations, pilot requests or other events) require tactical clearances. Most routine tasks have been removed from the Executive level due to intervention at the Planner level and the system support provided. The main task is to identify free airspace when issuing new clearances to those aircraft in the 'Concerned' group.

The underlying principle behind the above scenario is that by anticipating a large amount of the conflict detection and resolution tasks at the Planner level the routine Executive workload per aircraft is reduced. Much of this workload is therefore transferred to the Planner but, by concentrating skills and resources on resolving identified problems, it was expected to reduce the overall workload per aircraft This reduction in workload per aircraft in turn leads to a potential increase in capacity. The scenario had to allow for the possibility of Executive intervention on any aircraft whenever necessary. The scenario also significantly reduced much of the routine R/T exchange.

12. LAYOUT OF CONTROLLER SCREENS.

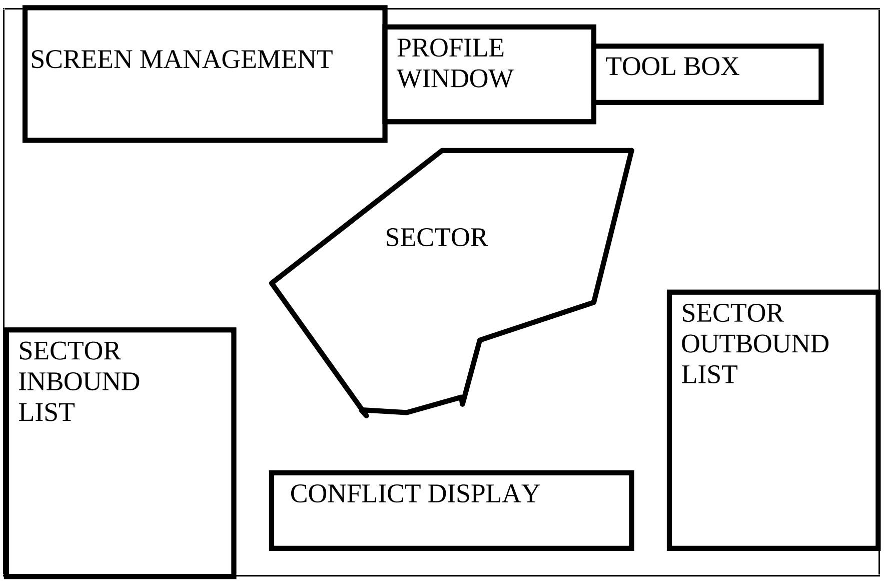
The series of illustrations show the displays at the same time but from different perspectives.
The time for each is 07.27 simulation time, when the number of aircraft in the two Executive sectors was at the peak, (32 aircraft).

Fig. 1 is the Executive full screen
Fig. 2 is the Executive screen showing the display effect of selecting a conflict (No. 2) from the Conflict Risk Display.
Fig. 3 is the Planner view of the sector including a view of a complex conflict situation involving the automated co-ordination function (based on SYSCO). The radar window shows the situation when the problem free group are suppressed.
Fig. 4 is the Planners radar window with no suppression of radar label information.
Fig. 5 is the Planner display as organised by the Maastricht controllers in accordance with their requirements.

12.1 Executive Screen.

The Executive screen was focused on a real-time, whole sector, radar window. Other windows were available for additional information or functions.

The illustration over page shows the following screen configuration.



Key to Executive screen layout

Screen Management	General, radar scale, ground speed, Concerned (problem) aircraft group
Profile window	Profile view of selected aircraft's flight plan
Tool box	Used to open/close other windows (except radar window)
Sector In and Out lists	Aircraft that have boundary conditions agreed but have not yet crossed the appropriate boundary. Re-sortable by time, level, entry point or alphabetically
Conflict Display	Output of Medium Term Conflict Alert function. Display range up to ten minutes into future.

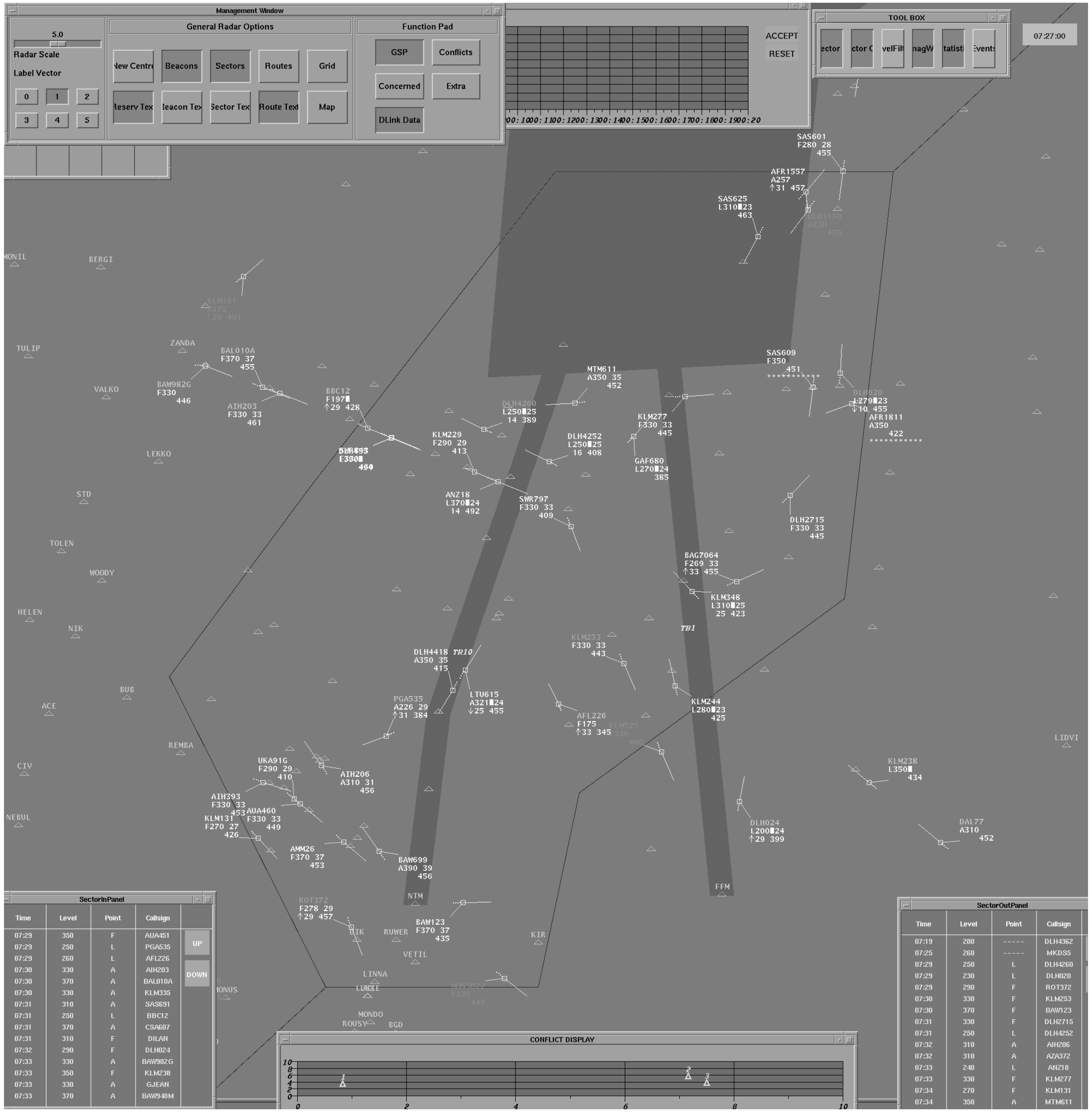


Fig 1. Full Executive Screen

The different label functions are described in Appendix D ‘Label Functionality’ page 52.

The orange callsigns are aircraft co-ordinated into the sector but not yet released to the Executive.

The blue callsigns are datalink equipped aircraft between 3 minutes and 1 minute from exiting the sector. The indication is that the automatic ‘change sector’ message is about to be sent unless the Executive actively blocks it.

The two labels on the right side of the sector are showing a Short Term Conflict Alert, (a flashing line of asterisks).

The dark blue block with two ‘legs’ is a military zone with two Tacan routes feeding into it. These are displayed within the HIPS profile display (see Planner Screen) in cross-section.

The ‘Sector In’ and ‘Sector Out’ panels can be re-sorted according to Time, level, entry/exit point or alphabetically by clicking on the appropriate title with LB.

Sector inbound lists attached to particular entry beacons were not used because of the random nature of entry/exit areas when using a direct ‘free-flight’ type scenario.

Note: some colours have not been reproduced accurately in this document.

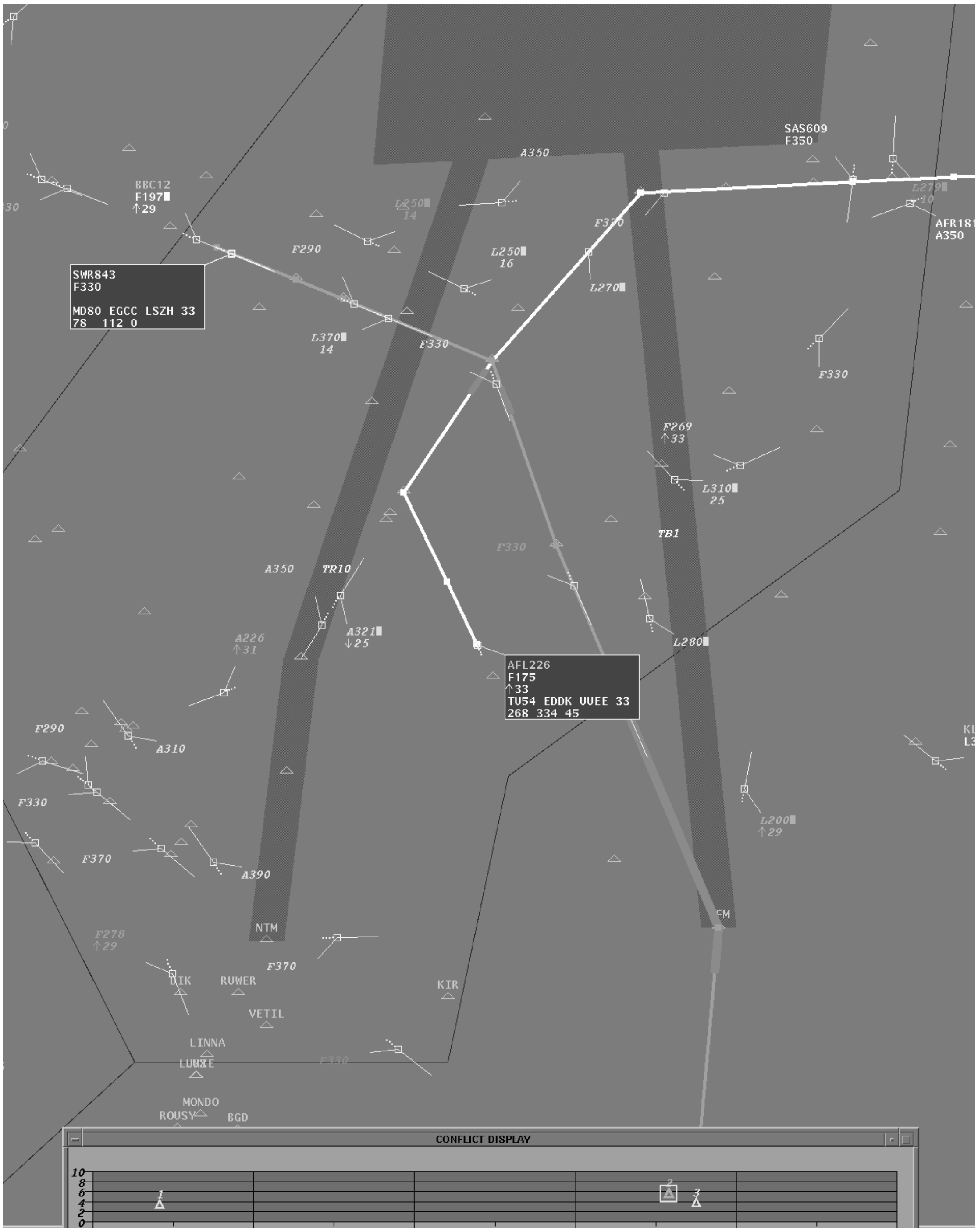
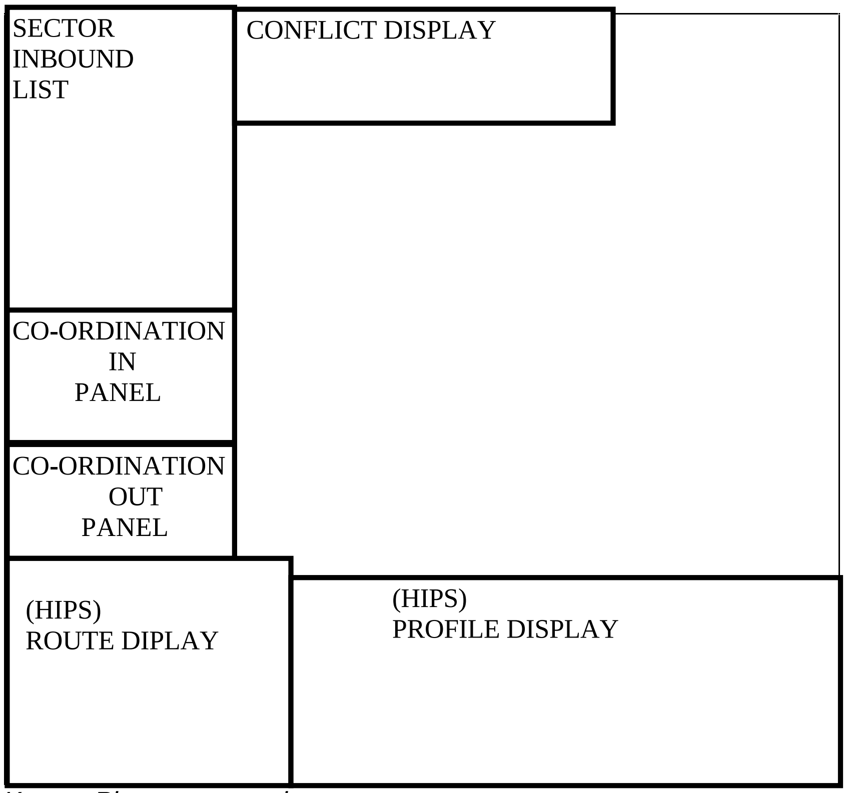


Fig 2 Executive radar window with Conflicting trajectories opened from Conflict No. 2 in Conflict Display.

This shows two Flight Legs opened,
SWR843 coloured brown with red segments indicating two conflict situations, and,
AFL226 in white, not yet released to the Executive but in conflict with the SWR843.
The colours white and brown are used to help differentiate the two flight legs.

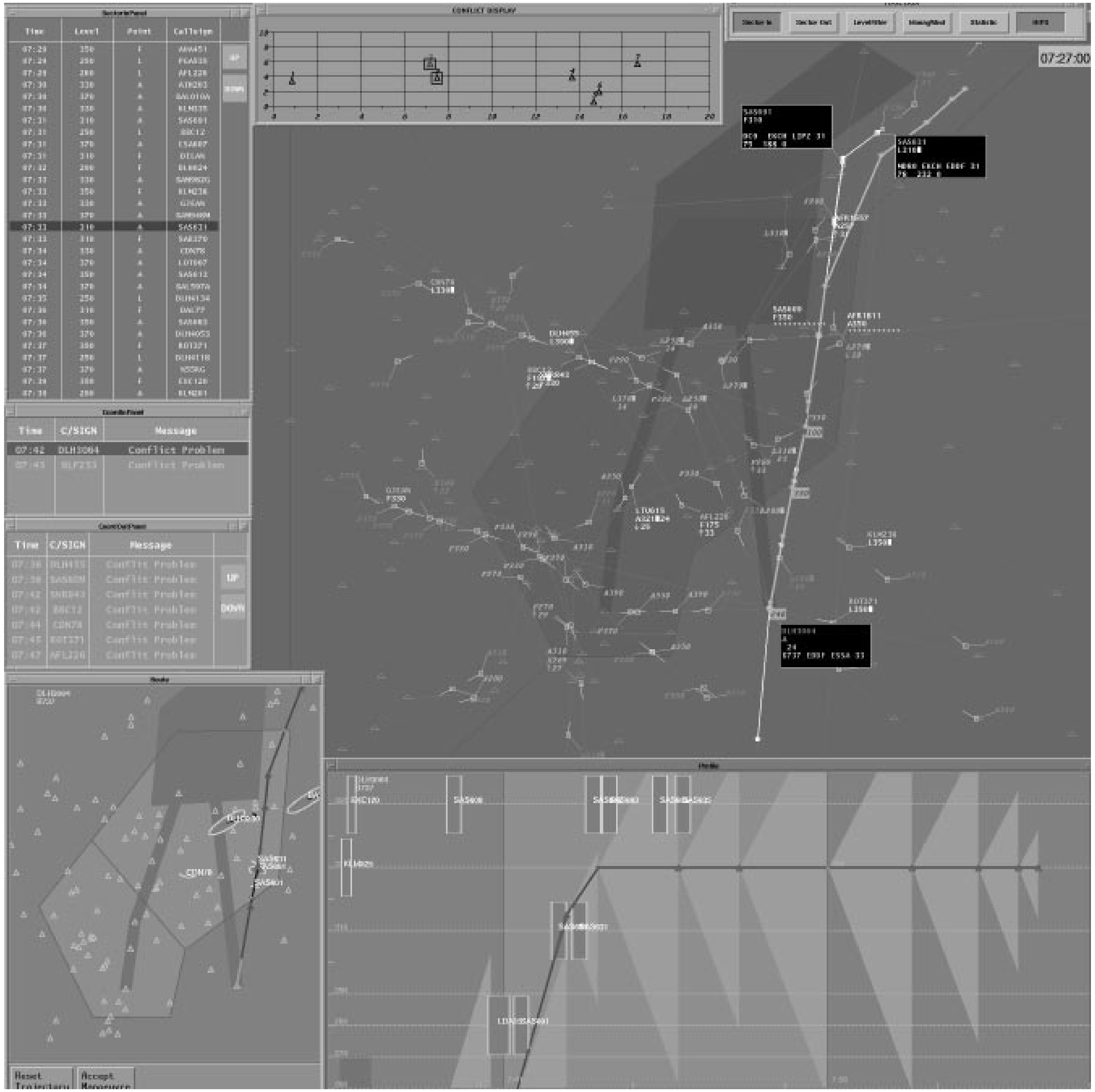
12.2 **Planner display**



Key to Planner screen layout.

Conflict Display	As for Executive except display range up to 20 minutes into future.
Sector Inbound list	Same as for Executive screen (note that if an aircraft is selected in one window any reference to it in other windows are also highlighted, cf. traceability of information)
Co-ordination-In Window	This ‘flags’ any situation where the automated co-ordination in process has been halted, normally due to a conflict being found within five minutes of the sector boundary.
Co-ordination-Out Window	As for co-ordination in except it refers to conflict situations blocking the automated co-ordination out process.
HIPS Route Display	This is the display of the chosen subject aircraft’s route through the sector and shows conflict zones and other environmental aircraft zones.
HIPS Profile Display	Displays chosen aircraft’s profile

NOTE The HIPS display used in AS09 did not have all the functions of the HIPS built within the PHARE Advanced Tools Programme. The time-based control element was excluded because it was too sensitive to use in a simulated Operational context and requires further development.



The HIPS has been activated to examine a conflict on the trajectory being requested by DLH3064 just airborne from Frankfurt north bound. The Flight Leg of the DLH is green to show that this is the plan that is on view in HIPS, it is the ‘subject’ aircraft.

The automated co-ordination process has been stopped on this particular aircraft. The Planner must now decide either

- to accept the profile ‘in-conflict’ and thus let the Executive resolve it in real-time, or
- modify one or more of the involved aircraft to resolve the problem and then re-start the automated co-ordination process.

Three conflict zones can be seen in the profile display, as well as in the plan-view display. as the DLH climbs to 330.
The DLH3064 ‘co-ordination in’ process has been stopped because of this conflict and the situation can be seen being highlighted in the Co-ordination in window.

The radar labels are suppressed for the ‘not-concerned’ group, see fig. 6 to appreciate label clutter when they are not suppressed.

Fig. 3. Full Planner Screen.

This illustration shows exactly the same sector situation as the previous illustration (Fig. 3). The difference is that all aircraft have full labels.

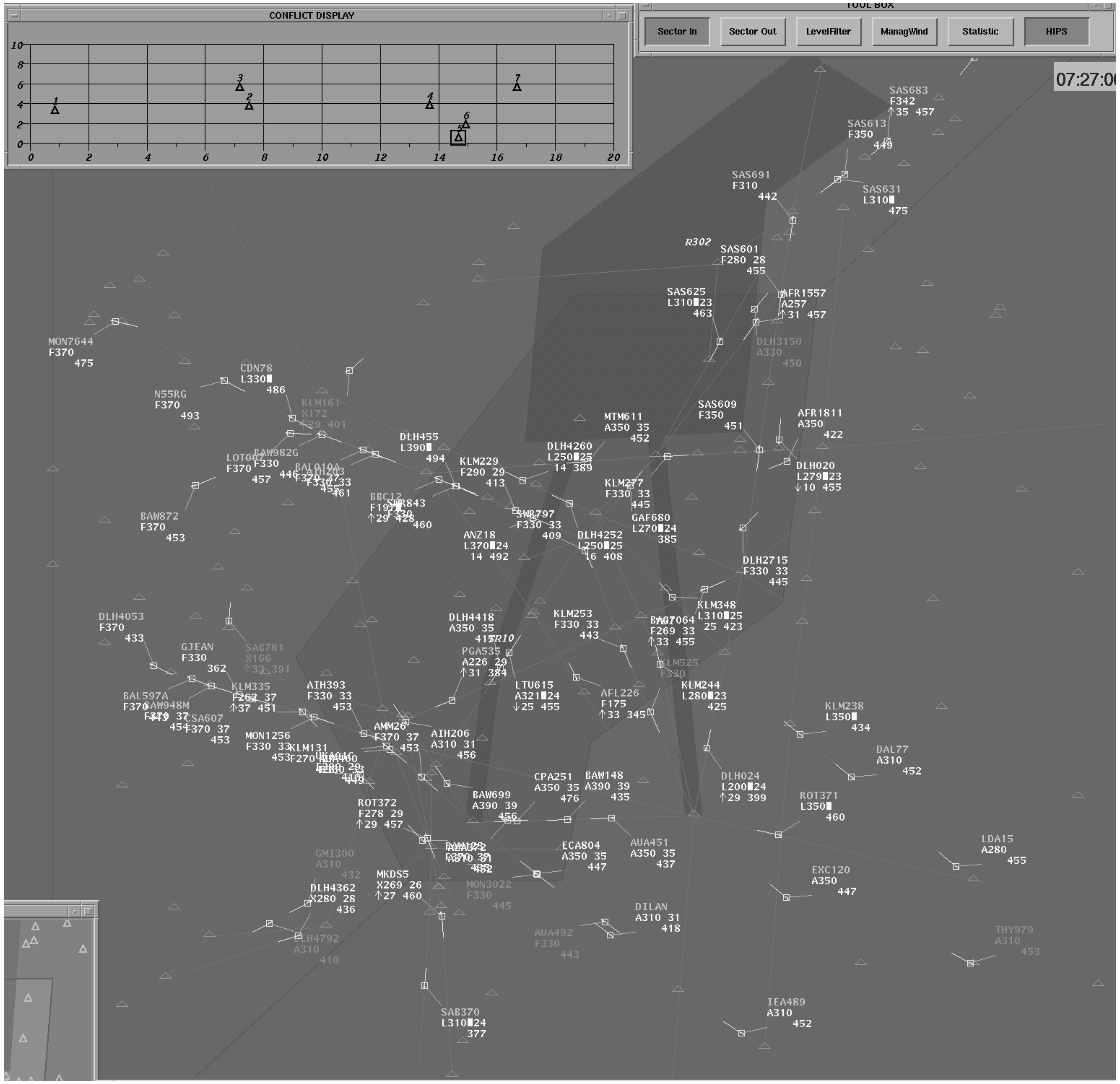
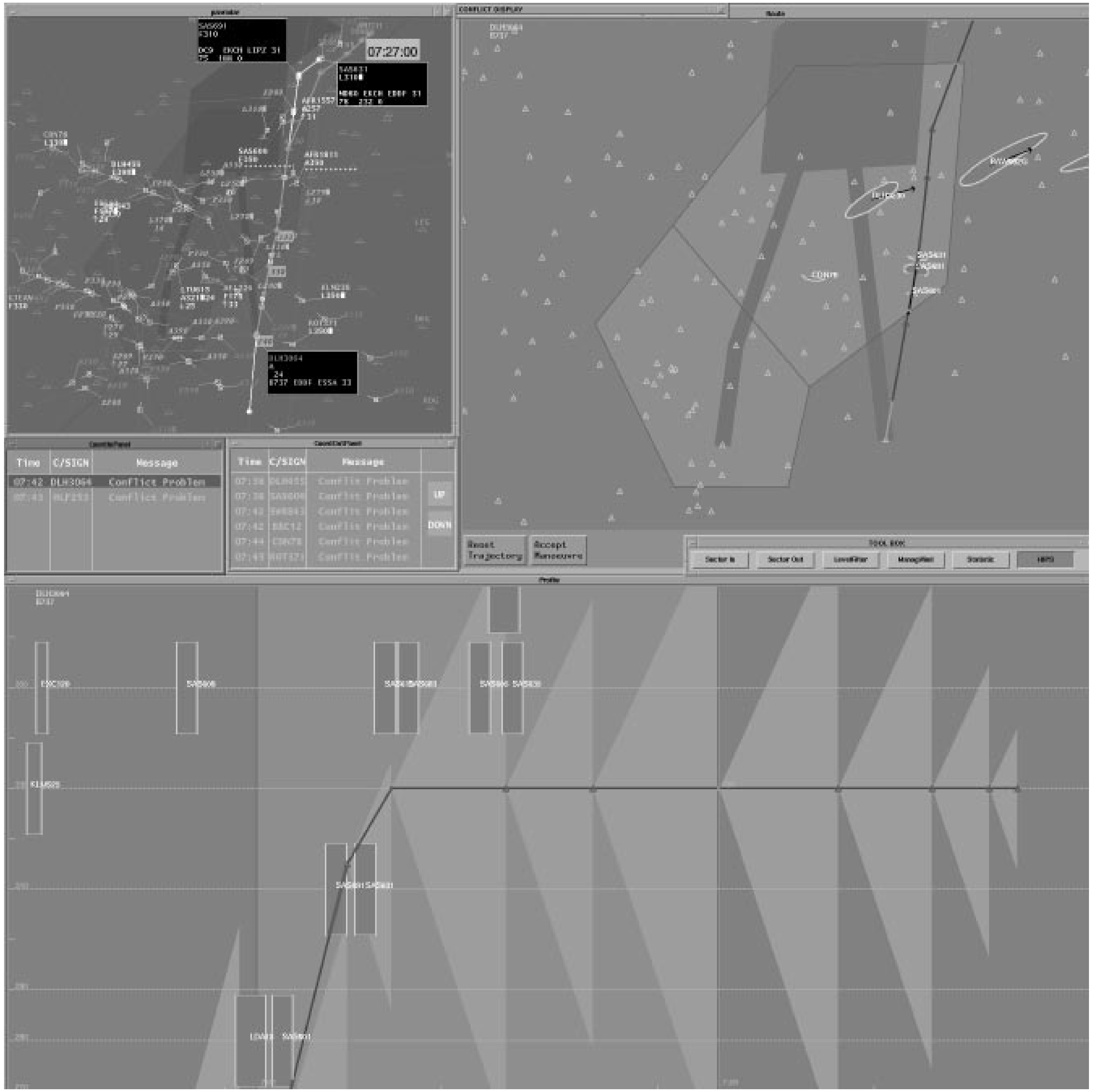


Fig 4 Planner radar picture no suppression of radar labels.



The scene is the same as the previous two Figures. The Controllers were given the opportunity to focus the various windows according to their requirements.

Note,

- Reduction in the size of the radar picture,
- Removal of Conflict Risk display,
- Removal of Sector outbound list,
- Prominence of HIPS display.

The emphasis that the controllers adopted was on searching for ‘problem group’ labels in the reduced radar window and then using these as access points to resolve the associated problems.

Approximately 150 aircraft passed through the sector in a one hour period.

Fig 5. The planner display after modifications by subject Maastricht controllers.

PART III: THE STUDY PHASE 2 - THE REVIEW

13. SCOPE OF THE REVIEW.

While technology is capable of delivering the functions described earlier in this document it is outside the scope of this prototyping study to determine their effects on ATC operations to any great depth. Such important issues as the possible effects of the loss of the 'party-line' information channel (R/T) on both controllers' and pilots' awareness need real-time simulations to allow reasonable analysis. However it was possible on the Rapid Prototyping platform, to go through the scenario in a real-time interactive mode, using simulated traffic patterns. A series of exercises was therefore planned to allow evaluation of the expected operational implications under these limited but, at this exploratory stage, still useful conditions.

14. REVIEW WEEK PROGRAMME.

The March evaluation period consisted of a series of exercises (of around one hour duration) in which the Planner and Executive were presented with a number of different traffic samples and carried out the roles described for them in the scenario.

The programme for the week was as follows:

	am	pm
Monday	Introduction and briefing	Familiarisation
Tuesday	Exercise 1 (100% Datalink)	Exercise 1 (continued)
Wednesday	Exercise 2 (75% Datalink)	Exercise 2 (75% datalink and military Zones)
Thursday	Exercise 3 (100% Datalink) increased Traffic sample	Exercise 4 Direct routings
Friday	Debrief	Debrief

Extensive discussions took place both during and after each exercise. The comments made by the controllers, about the scenario and the functionality developed on the Rapid-Prototyping platform, have been included in this report where possible. The use of the prototyping methodology for obtaining user feedback generated a lot of information. This information, while not being completely reported here, will be used when defining future improvements to the platform.

15. AIRSPACE AND TRAFFIC SAMPLES.

The study was based on a simulation of Maastricht Upper Airspace (FL245 and above) using modified versions of the RUHR and OLNO sectors. (see map).

Traffic samples were established based on the peak day of September 1994. This actual traffic was used to provide samples based on two traffic levels one equivalent to current peak and the other enhanced by 70% over the peak.

The higher traffic level simulated gave the following sector loads.

	Planner sector	Executive RUHR	Executive OLNO
Throughput, aircraft per hour	157	(≈ 86)[1]	(≈ 71)[1]
Instantaneous Peak sector load, (aircraft in sector)	32	28	21

[1] The totals for the Executive sectors are approximated. This is because the Planner worked in advance and received aircraft 20 minutes before either Executive, thus the same time slice for all three positions will show different totals.

Two scenarios for aircraft equipment were simulated; 100% datalink and 75% datalink. The principal effect of this was, in the latter case, to limit the possibilities of planning intervention in a proportion of the identified conflicts.

Most exercises were run with no military activity. However some exercises included the idea of a military zone plus TACAN routes being active, the effect of this being to limit the amount of possible direct routings.

A direct routings scenario was used for one exercise at the higher traffic levels.

16. OUTPUT FROM THE REVIEW WEEK.

The output from the review week was in the form of subjective opinions from the participating controllers and some observations from the project team based on the behaviour of the controllers during the exercises. These have been integrated into the report where necessary.

The controllers also commented that one week was not sufficient to fully understand the demands on the roles of controllers, pilots and system. As it is important to obtain the viewpoint of current users, it is essential that a reasonable period of adjustment is available to allow reflection on ideas and procedures being investigated. It is a big step from the world of current operations into an exploratory study such as AS09. More time to reflect would have been appreciated.

Part IV of the report presents the results of this review period. They are presented in three chapters; The effect of 4D-FMS integration; The role of the controller in system supported scenarios and The effect on current day procedures.

17. AIRSPACE DIAGRAM.

The diagram shows the 'STUDY' Planner sector, subdivided into two Executive sectors RUHR and OLNO, both effective from Flight Level 245 and above.

The 'ACTUAL' RUHR sector at Maastricht is shown as well to allow comparison. This was not used in the study.

---------- broken lines are the boundaries between the three FEED sectors used to
complete the environment.

PART IV: OBSERVATIONS , CONCLUSIONS AND RECOMMENDATIONS

18. EFFECTS OF 4D-FMS INTEGRATION.

18.1 Overview.

One of the main objectives of this project was to take a close look at the possible implications of integrating 4-D FMS data into operational ATC. This integration should enable a substantial increase in the capacity of the ATM system.

The underlying assumptions were that:

- 4-D FMS data provides ATC with knowledge of the expected position of the aircraft 20 minutes or more into the future.
- This data is used to detect 'conflicts' between individual aircraft.
- A Controller can resolve these detected 'conflicts' well in advance of their predicted occurrence by modifying the 4-D FMS data on the ground.
- The modifications are negotiated and agreed with the concerned pilots.
- The aircraft navigate according to the agreement.
- Once a future situation has been agreed between all parties then all must work to maintain that agreed situation.

This raises certain questions about the operational constraints of using 4D-trajectories in real-time:

- How should the responsibility for checking, modifying and negotiating trajectories be divided between Planner and Executive? (Division of responsibility)

- Once a plan has been agreed what problems are experienced by the Executive in maintaining or modifying the plan in real-time? (Flexibility when maintaining plan)

- What type of co-ordination, both ‘planner-planner’ and ‘planner-executive’, is needed to maintain reasonable responsiveness in this pre-planned environment? (Co-ordination of boundary conditions and real-time executive actions)

- How do non-datalink aircraft fit into the concept? (Aircraft equipment)?

These questions are now looked at in greater detail.

18.2. Division of responsibility (Strategic and Tactical Control)

The responsibility for modifying and negotiating trajectories, via datalink, was allocated to the Planner because of the large amounts of data being passed between the ground and aircraft, often in the form of geographical co-ordinates, and the time delays implicit in the expected negotiation process.

The issuing of clearances to the aircraft therefore required clear, practical and flexible protocols to determine at any point in time which Planner had the authority to modify plans/trajectories (and issue them via datalink) and which Executive had responsibility for the aircraft (and executive authority via R/T).

It was also considered necessary to reduce planner-executive verbal co-ordination, because of the demands of a high density environment and the need for the controllers to keep the 'system' informed of their actions at all times. (It was assumed that if each modification to a trajectory required co-ordination then workload would increase exponentially with traffic load.)

The following protocol was devised to separate responsibilities.

The Planner was responsible for de-conflicting the trajectories more than ten minutes ahead of the aircraft. (This dynamic 'buffer' period was changed from 10 minutes to 8 minutes for the final assessment to improve flexibility). Effectively a plan was being established by the Planner for a time period always 10 to 20 minutes into the future, i.e. at a Strategic level. The focus of this action was to stabilise the situation and thus to provide protection for each aircraft's plan for the next ten minutes of real-time (the buffer period).

The Executive was responsible for safety in real-time and could thus intervene on any aircraft, under his/her control, at any time. However if the act of intervention did not also include a check-with and update-to the flight plan data base, then the aircraft would lose the protection of being on a strategic plan. The aircraft would therefore be under tactical control and would be identified as such. The AS09 organisation allowed the Executive to intervene in one of two ways, strategically or tactically. The choice was the Executive's and the decision would be based on the time available to execute orders.

18.3. Flexibility in a pre-planned environment.

The requirement of the aircraft to follow an agreed plan, which should be conflict free, impacts on the flexibility of the pilot and the Executive to make instant changes to plans. Modifications made in real-time need to be minimised because the Planner is establishing a conflict-free situation assuming that the trajectory data does not change. The flexibility for a Pilot to request modifications to his flight path could thus be significantly reduced.

Within this possible pre-planned environment requests for modifications from the pilot should normally be made at the Planner level, 15 to 20 minutes before they are to take effect, so that all the possibilities and consequences are understood. There should always be a capability for short term modifications but this should be for exceptional situations only. If real-time modifications are required then it often becomes difficult for the Executive to make the necessary modifications to a plan or to return an aircraft back to 'plan'. This is because of the four dimensions involved (An additional demand is co-ordinating the changes with the next Executive or Planner).

Why complicate the situation for the Executive?

The problem is that if a system is designed such that both safety and capacity are functions of having a high level of pre-planned actions, then that system will start to degrade rapidly if un-planned actions happen regularly. To control this degradation the system must either:

- allow updating of the plan whenever unplanned events occur in real-time, (this could become destabilising if it is a common event), or,

- be planned on looser constraints, thus allowing individual aircraft more freedom for movement but also reducing the capacity at the planning level. (This does not necessarily correlate with reducing the real-time capacity if aircraft are allowed to enter at short notice under Executive control. This structure would need careful control to prevent Executives from rapidly becoming saturated by last minute requests.)

Obviously if safety is dependant on the plan being maintained then the plan must be updated to take into account any unplanned events. However, to do this, any action must be defined as having a start point (relatively easy) and an end point (sometimes very difficult).

The interface had therefore to be built such that updating the plan would be relatively quick and easy. This would allow requests for early descent, new cruise level or route change to be processed in real time, whilst maintaining the protection afforded by the Medium Term Conflict Alert function of the flight plan database.

The interface also had to allow for those situations where either time or the event itself did not allow an end point to be identified. These situations, such as Short Term Conflict Alerts or aircraft emergency manoeuvres, were considered Tactical in nature and were identified as such at both a graphical and a functional level.

18.3.1. Executives strategic control and tactical intervention.

It became clear that the actions of the Executive need to be placed into two categories:

- those where the end of the action could be identified; strategic,

- those where the end could not be identified; tactical.

It was necessary to differentiate between these two types of action so that :

- the Executive always understood the effects and limitations of any action,

- the Planner was aware of the unplanned nature of real-time events, these would render the plan unusable at the Planners level of functioning and

- it was clear at the system level which actions should modify the flight plan data base and thus affect the MTCA function and which actions should not. It was not considered reasonable to allow tactical, open loop instructions to update the flight plan data base. Without a definite end-state being identified, assumptions will be made by the system itself to close the loops. This would lead to false, inaccurate information being supplied to the Planner and thus degrade the plan being established by him.

Thus to differentiate between the two types of intervention the Executive could either be:

- in Strategic mode; by opening up the flight leg display (see Appendix D on label functions), signifying to the system that the plan was opened and being updated or,

- in Tactical mode; instead of opening the flight leg inputs are made directly through pop-up menus, for flight level and speed, or through the elastic vector for headings. (see Appendix D on label functions).

Thus an attempt was made to allow for flexibility, but more testing in a simulation environment is needed. It became evident during the exercises that these restrictions to Executive behaviour can be reduced in impact if the Planner uses wider-than-radar separation standards to establish the initial plan. Suggested values for further work could be 10 miles along track and 2 flight levels where an aircraft is descending or climbing. The effect on the capacity of such an organisation when the Planner establishes separation using wider standards than the real-time situation requires must be assessed. This would allow for greater deviation before triggering conflicts and would consequently increase flexibility.

18.4. Co-ordination aspects (Planner-Planner, Executive-Planner)

The use of the accurate 4-D FMS data requires strict co-ordination procedures to ensure that all parties who have access to the data are aware of its current quality, i.e. is the aircraft still following the agreed trajectory or not?

It is also essential to be able to guarantee that the quality will be maintained when transferring the authority to modify it from one Planner to the next, i.e. the aircraft will achieve the agreed boundary conditions otherwise co-ordination will be required.

18.4.1 Planner-planner co-ordination.

The co-ordination process, in a distributed, common data base organisation, is more of a transference of authority, from one Planner to the next, to both edit the trajectory or flight plan data of an aircraft and communicate with the aircraft. This process needs to be completed in sufficient time for the receiving Planner to start using the data appropriate to his sector. Once the process is complete the 'giving' Planner has no authority over the aircraft trajectory data.

In other words if Sector B Planner wishes to resolve a conflict predicted to occur in Sector B in 20 minutes time and the aircraft is still in Sector A then certain conditions must be observed:

- Sector A must have transferred trajectory edit rights to Sector B (to prevent two people editing the same trajectory).
- Sector A must have transferred communication rights, datalink, to Sector B (to allow the possible protracted negotiation process).
- Sector A Executive should not modify the trajectory up to the boundary, unless it is essential to maintain safety (this ensures that the boundary conditions and thus the subsequent trajectory will be maintained).

Obviously this inter-sector (Planner level) co-ordination process tends to reduce the flexibility to respond to short term situations (less than 20 minutes away in time). Thus it becomes an objective to either:

- reduce the number of Planner sectors, (to reduce the number of Planner boundaries), or
- to change the nature of the Planner sector boundary such that this rigid co-ordination process is not required.

A possible approach that merits further study is to create Planner sector boundaries at a graphical level (an HMI level) but not to carry this division down to the functional level of the system. Thus the Planners could be aware of the limits to their authority without being constrained by the functional layer of the system.

Another aspect of the co-ordination function that required deeper examination was the automated acceptance of non-conflicting aircraft. It was not clear whether the co-ordination function, even of non-conflicting aircraft, was so essential to the understanding of potential sector activity in the next 20 minutes that it needed to be retained in order to keep the Planner in the loop.

18.4.2 Communicating Executive actions to the Planner.

Any action on an aircraft trajectory made by the Executive could affect the information that the Planner was using. Clear information and display procedures were required so that the Planner was always aware of the state of the trajectory information of any aircraft under Planner authority.

The information requirement was mainly one way, i.e. the Planner needed to be informed whenever the Executive started to intervene on any aircraft in a way that either changed its plan or took it off plan. This was accomplished by sending a message to the appropriate Planner whenever an Executive made an input to modify an aircraft trajectory or simply take it off-plan. The message prevented the Planner from editing the trajectory until the ground data base had been updated by the aircraft’s FMS as to the consequences of the Executive action. The blocking of Planner editing rights could last several minutes if, for instance, the aircraft was put on a heading.

The two types of Executive actions, Strategic or Tactical, had the following steps.

When an Executive intervened strategically, (by opening the flight leg to update the data base), there were two steps in the process:

1) Changing the plan. As soon as the Executive made an input to modify route, flight level or speed a message was sent to the Planner responsible for that plan. This message blocked the Planner from making modifications to that plan, even if he was actively involved in that process. This Planner could be in another Centre. Thus requiring close connections for participating Centres.

2) Receiving aircraft generated update to plan. Because the Executive could only communicate with the aircraft by r/t, the commands that could be

delivered could not be as complex as those delivered by datalink, consequently a ground model was used to temporarily update the flight plan data base to allow the MTCA to function. When the pilot downlinked the more accurate FMS generated trajectory the ground data base would be updated. The Planner could not modify the plan until the FMS update had been received.

When the Executive intervened tactically, (here the flight leg is not opened) there were three steps.

1) Enter tactical instruction. As soon as the Executive made an input to modify heading, speed or flight level three effects were built in:

- a frame was placed around the radar label on both Executive and Planner displays. (This remained until the flight plan was updated by the Executive opening the flight leg and making the necessary inputs to close the loop).
- a message was sent to the Planner responsible for that plan. (This message blocked the Planner from making modifications to that plan, even if he was actively involved in that process).
- a message was also sent to the flight plan database, so that if that plan was in conflict with another in the MTCA function, then the symbol in the Conflict Display would be changed from a triangle to a circle. (This indicated to the controller that the plan was still in conflict but that something was uncertain in the quality of that plan and thus the predicted conflict may change in nature or disappear).

2) change the plan, and

3) receive aircraft generated update to plan. When the tactical manoeuvre was completed it was necessary to return the aircraft back to plan or update the plan. This involved returning to the two steps as for the Strategic process above.

It was evident that tactical control of an aircraft not only invalidates the plan established for that aircraft but also introduces a rogue element into the plan established around that aircraft, and makes further planning subject to change. **Therefore tactical intervention is an action to be avoided as much as possible.**

18.5. Aircraft equipment

The procedures to be adopted for non-equipped aircraft (in particular non-datalink equipped) and the way that they are integrated into the overall traffic pattern need to be defined. Does the Planner controller have a responsibility in trying to define a plan for such aircraft? Do they have special airspace or routings? With what priority does the Executive treat them? These are just some of the issues to be examined.

In the study there was complete integration of equipped and non-equipped aircraft into the same airspace. The Planner could only communicate with datalink-equipped aircraft and this meant that he tended only to consider these aircraft for manoeuvre when resolving conflict situations.

The issue of what type of information is communicated via datalink needs to be examined. The AS09 scenario assumed that datalink was used to transmit 4D constraints points which were used to calculate a 4D trajectory to be flown by the aircraft. The question of what data will be transmitted (including other ways of defining 4D trajectories) and the possibility of sending controller orders needs to be examined.

19. THE ROLE OF THE CONTROLLER IN A SYSTEM SUPPORTED SCENARIO.

19.1 Overview

The effect of using predictive data to establish and agree an accurate plan for each aircraft passing through a sector has the effect of changing the tasks, working methods and responsibilities of the controllers. The objective of AS09 was to keep the Controller in all the decision making loops but to use system support for as many of the routine tasks as assumed technologically feasible.

How is the controller role and working methods changed in these new scenarios? In particular:

- What is the effect on the controllers of becoming more system 'driven'?
- What system support does the controller need to remain in contact with the sector situation?
- What are the responsibility issues involved when the system has such a large role to play?

19.2 The Planner Controller role

The role of the Planner became central to the efficient functioning of the AS09 ATC system and the key to its capacity. The role has two main characteristics:

- It has become very dependant on the system for identifying problem situations
- It has expanded into the domain of the Executive by giving the Planner the capability to resolve situations at a strategic level within the Executive sector using techniques which could be regarded as tactical by nature.

The dependence of the Planner on the system is a result of the increase in:

- the size of the planning sector (to reduce inflexibility imposed by boundary co-ordination)
- the number of aircraft passing through the airspace,
- the amount and complexity of the data attached to each aircraft,
- the more random nature of traffic patterns resulting from direct routings.

It should be noted that currently Planner roles differ between centres and even between sectors in the same centre. It is often the case that the

Planner, while having a minor role, plans traffic to ensure that the Executive is not overloaded. This overload is not simply due to a certain number of conflicts but is directly linked to the traffic situation. The Planner uses his experience of what the Executive will be doing to assess whether potential conflicts he has identified will lead to a critical situation.

In the new scenario the Planner, while directly resolving conflicts and thus taking work away from the Executive has no longer a comprehensive picture of what the Executive is, or will be doing. The intimate knowledge of what is happening in real time has therefore been lost and the task of preventing Executive overload has potentially been made impossible.

The role has changed from one of explicitly preventing Executive workload overload to one of conflict resolution.

Technological advancements now provide the possibility of reducing the Planner task to a system-driven trouble-shooter. It is only a small step from AS09 to allow the system to make the decisions in the situations being presented by it to the controller. In this case the human role would change from being a Controller to being a System Supervisor. This was recognised by one of the Controllers with the comment (paraphrased) that *'either we have a system where the human role is of a Supervisory nature or we keep the Controller role and provide support to it, not reduce it to responding to system stimuli'* .

This raises two questions:

- Is it possible to envisage an intermediate situation where there are large amounts of detailed 4-D FMS generated data and higher sector throughput without providing a very high level of system support to help manage this data?

- What are the overall effects of combining Medium Term Conflict Alert, System Supported Co-ordination, Datalink communications and powerful graphic tools all of which initially appear useful controller support functions?.

19.3 The Executive Controller.

The Executive tasks will probably change as traffic patterns become more dispersed because there will be more conflict points, many of which will be on or close to sector boundaries because of the random and dispersed nature of flights in direct route scenarios. Automation and graphic displays also have the potential to induce changes to roles.

Within the AS09 scenario the Executive role was changed in four ways:

- The Executive sector had been opened up because most problems traditionally managed by the Executive had been resolved in advance by the Planner's actions. The Executive was no longer "King" in the sector, a major change to current practice.

- The role required the controller to monitor for system detected deviations to ensure that aircraft followed plans. If there were deviations then the flight plan/trajectory data base had to be updated as quickly as possible so that the Planner could continue to work on those plans affected by deviations.

- The ability to intervene tactically in order to accommodate any short notice inability for an aircraft to keep to a plan required system support. This was due to the traffic level being increased to a level not normally manageable by the Executive, as well as the reduced 'picture' of the instantaneous traffic situation.

- When a plan was modified authority was temporarily taken away from the Planner until the process was completed and the new plan was established. (This could have a destabilising effect on the Planner).

The area of the study concerning the division of a sectors traffic into two populations, 'Concerned' and 'Not-Concerned', was received favourably by the controllers until they were expected to resolve un-planned situations. As soon as any unexpected situation occurred which required the immediate intervention of the Controller it was observed that difficulties were being experienced in understanding;

- what were the implications of what is happening and

- what were the required actions to maintain the safety of the aircraft in the sector (Concerned and Non-concerned).

Thus it was obvious that the division of traffic into concerned and non-concerned was potentially unsafe when unexpected situations occur, unless very rapid and accurate support could be provided by the system (a situation not easy to imagine at present).

The Executive in this scenario had a very much reduced role in managing the traffic situation but was still expected to intervene rapidly and effectively whenever safety was compromised. This was in an organisation where:

- the Executive did not have an overall 'picture of the traffic situation because it is itself more complex and heavier than current levels, and

- aircraft could 'jump' instantly from the 'Not-Concerned' into the 'Concerned' group, because of track deviation, STCA or other unplanned events, which required immediate analysis of the situation by the controller.

To be effective in this role the Controller would require very quick and effective system support to help identify the available airspace where the manoeuvres required to maintain sector safety can be executed.

In essence the question identified was:

How can the controller stay in the 'loop' of controlling a sector when traffic levels are increased and the system is processing all of the 'routine' data transfers?

As a result of the exercises the question of responsibility was raised as a major issue by the participating Controllers. This question of legal responsibility is fundamental for controllers and comes down to the question:

If I, as an Executive, have not established the traffic plan, and I have limited capability in understanding the whole traffic situation because of the increased traffic density and complexity, and I am now relying on the system to detect problems and to identify solution zones then - How can I still be held responsible for the safety of the sector? If I am no longer responsible for overall safety who is and where is the dividing line drawn?

19.4 Decision making and the control process in computer aided real-time systems.

An alternative title to this section could be "I keep making decisions but will somebody please tell me what's going on!".

This section has been separated from the previous sections on controller roles because it describes a particular effect that was observed during the AS09 assessment phase, involving two operational controllers from Maastricht, that needs highlighting.

The behaviour was not observed under controlled, experimental conditions and thus cannot be considered absolute or definitive. However even data of a subjective nature can help to understand what the human role could be in systems that are heavily reliant on computer assistance.

An underlying trend in the computerisation of systems is to allow the computer to do all the tedious, routine data processing tasks. This is commensurate with the known strengths of computers for fast, efficient, accurate processing of large quantities of data. The human, conversely, is relatively limited in this capability but is good at making decisions, often based on fuzzy data, and is innovative.

It has been concluded from this that it is reasonable to allow the 'system' to process as much data as possible and to structure the human role as a decision maker over 'exceptional' situations. An objective of the researchers within AS09 was to try to understand the possible developments in controller roles that could result from providing various levels of computer support.

The philosophy adopted in respect of determining controller roles has been described elsewhere as 'Control by Exception'. That is to say the computerised aspect of the system handles the routine data processing tasks, according to simple rules, and the human, the controller, handles the exceptions such as conflict resolution which require innovative thinking and rapid decisions.

Thus in AS09 the 'system' had been programmed to make a simple test: Is there a conflict on this trajectory? Yes or No! Any conflict situation discovered caused an exception to be raised which stopped the co-ordination process on that aircraft until the relevant Planner examined the situation, determined his own resolution, without any advisories being provided, and communicated the resolution to all interested parties. The controller then reactivated the co-ordination process for the aircraft, which would then be able to complete successfully without further intervention.

The conflict detection function was extended beyond the co-ordination process into the actual sector where the MTCA function picked up conflicts between trajectories.

Within AS09 the Planner effectively received support in two areas:

- the task of transferring the boundary conditions data on each aircraft to the next sector, (System supported co-ordination), and,
- the task of searching for conflicts, (Medium Term Conflict Alert).

The Executive controller also received support in two areas :

- division of the traffic into two populations and
- the task of assuming and transferring datalink equipped aircraft.

The role that was most affected by this support was the Planner role. The Planner had access to the information on each inbound aircraft, through the sector inbound list, from approximately twenty minutes before sector entry. Because of the automated co-ordination function, the controllers did not need to take part in receiving data from the next sector, but, more importantly, it was not necessary to verify the data on incoming aircraft. This verification task was effectively taken over by the 'system' because it was the 'system' that performed the conflict search aspect of this data transfer task. Thus the controllers relied upon this MTCA function and did not take an active part in verifying the entry conditions.

The issue involved here is that within some data transfer tasks there is also a verification procedure. As each inbound aircraft is notified to a Planner sector the conflict detection function (MTCA) informs him whether the aircraft is conflict free or not. As a result he has to decide "Do I trust this MTCA or not?". If he does then he no longer takes any part in the verification process and will simply intervene when the system tells him to.

This reliance on the MTCA is a state that would occur over time within an operational environment, the acceptance period being dependant on the experienced accuracy of the function. But at what point would the controllers discover the limits of the MTCA and what would be the consequences of this limit being reached or even passed?

The state reached in AS09, because it was a perfect world, was that of total reliance on the MTCA which caused the comment *"I kept making decisions but I had no idea what was going on in the sector!"*

There are thus two issues identified here,

- how are the operational limits of computer based functions established and tested?

- once a computer based function, such as MTCA, has become accepted, and the controllers have established a reliance on it, who is in control ?

It is clear that if a controller is to be held wholly responsible for safety in a sector then there is a need to keep that controller in sufficient contact with the system processes to remain in a position of control.

An extension to this is to determine which tasks are capable of being assigned to the system, and in what way, such that the controller remains in overall control.

It is possible to see systems being developed which take the controller into the situation of performing a solely decision making role without being in control. This is the state where decision making and control functions have been isolated and separated and are being performed by different, possibly isolated parties. These situation need to be identified clearly to ensure that responsibility is placed correctly.

It is clear from the AS09 exercise that the role of the human, in controlling real-time systems such as Air Traffic Control, ***can*** be aided by computer technology ***but*** that being the decision maker is a task that does not necessarily equate with being in control. This particular effect can be translated into any real-time control process.

This is a specific area where more research and experimentation are required urgently because computer based aids such as MTCA are being specified for use in several real-time radar based ATC systems.

20. EFFECTS ON CURRENT DAY PROCEDURES

20.1 General

Many of the procedures in place today exist for historic reasons and are closely linked to today's airspace structure and operational procedures. There are a large number of questions on how current day ATC procedures will be changed by the adoption of new procedures which depend on 4D FMS. The AS09 study has highlighted many areas where further investigation is needed. These areas include:

- departure clearances
- inbound /outbound separated levels
- the future requirements of the military
- pilot requests
- standard R/T and verification procedures
- co-ordination requirements
- interface with Arrival Managers and the CFMU

It what follows many of the examples, although specific to the RUHR sector, are illustrative of a general problem.

20.2 Departure Clearances

The issue of departure clearances is an area which requires clarification. The question is; At what time (and by whom) will a departing aircraft be given a conflict-free clearance to climb to its requested flight level? Currently, Frankfurt departures , for example, have a standard clearance on a SID, the final clearance to climb above FL240 is provided by the RUHR sector depending on known traffic. Under the advanced scenario can we assume that sufficient data will be available for some (or all) departures to receive clearances to climb to cruise levels which require no further executive action or will there be a need for extended SID's to cope with the uncertainty of departure time and the complexity of TMA traffic?

20.3 Inbound/Outbound separated levels

Currently, for the RUHR sector, departing aircraft are cleared from Amsterdam to FL250 or below while inbound traffic is handed over to them at FL260 (or above). This ensures a procedural separation and leaves the final clearance on climb to a tactical decision by the Executive. The complexity of airspace around major airports could prove too unstable for the type of individualised planning detailed in AS09. However FMS capabilities allow aircraft to follow trajectories more accurately whether they are individualised or not.

20.4 Military traffic

What will be the impact of military traffic and areas in the new scenario? Executives today essentially operate by respecting a number of constraints on available airspace due to military zones being active, respecting a number of level restrictions due to Tacan routes etc. and dealing with requests for direct routings on a tactical basis by co-ordinating with the military. For the future scenario can we assume that such airspace restrictions will be built into the planning process and that opportunities for 'tactical' direct routings will still exist? This issue is especially important given the high traffic densities foreseen.

20.5 Pilot requests

Current procedures allow for a great deal of flexibility in the way that traffic is handled. Pilots can request different routing and level changes and, in a large number of cases, be given their preferred option due to the flexibility of the Radar controller. It is supposed that some of the need for this flexibility could be removed in the future by, for example giving more direct routings or allocating requested flight levels at the Planner level. What needs to be assessed is how many of the current pilot requests can be reasonably predicted in advance and incorporated into the agreed trajectory using FMS technology. What will be the freedom of action available to the Executive for the remaining unavoidable requests?

20.6 Standard R/T and verification procedures

Routine R/T exchanges between controller and pilot while significantly adding to the R/T loading serve several purposes. These include:

- building up situation awareness,
- verification of situations and,
- providing 'party line' information.

The process of responding to a first call from a pilot acts as a valuable memory aid for the controller in building up a picture of the traffic. In addition the act of the pilot reading out his current clearance enables a visual check to be undertaken by the controller. Finally the fact that R/T calls are monitored by everyone, while potentially increasing the possibility of mis-understanding, adds a valuable 'party line' element to the environment. This coupled with the ability to understand the 'context' of a message by 'subjective' information such as speed of delivery, tone in the voice etc. means that the act of replacing R/T by the technically possible means of datalink has potential safety implications which will be very difficult to assess.

20.7 Co-ordination requirements

The form that co-ordination will take in the new scenario is unclear. It is not sure that existing proposals for automatic, system aided co-ordination have been defined by fully taking into account the impact of the new 4D-FMS scenarios. A fundamental look at why existing procedures exist and whether they are still relevant under AS09 type scenarios is needed. It is also possible that a general purpose co-ordination process will be difficult to define and that a 'case by case' approach will be necessary.

20.8 Interface with Arrival managers and CFMU

The volume of traffic envisaged in the time period for the new scenario clearly means that Arrival Managers will be present at several major airports. These will define constraints (speed, time and level etc.) which the Planner will need to respect. It is not fully clear what range from an airport the constraints will affect operations and what will be the impact on the Planners freedom of action. However, Arrival Managers are being implemented, and they will have an impact on the management of sectors such as the RUHR whether there is an AS09 type scenario or not!

In addition the introduction of the CFMU (strategic and tactical) will, presumably, have a significant effect on the pattern of the traffic demand presented to the Planner. This effect is not yet known.

20.9 The use of headings to maintain separation.

Whenever the Executive controller needed to give a tactical change to an aircraft heading a graphical tool, very similar to that used in ODID IV, was used to input the value of the heading into the system. This was referred to as an ‘elastic vector’,

The elastic vector tool did not map onto the controllers requirements for using headings to control aircraft. This was because the tool has no notion of drift. When strong winds are introduced into a simulation run the aircraft can often have up to 30 degrees or more of drift in order to maintain a track between points. As soon as the controller wants to assign a heading to an aircraft there are two possible scenarios, either

- The aircraft can be told to turn left or right in relative terms, i.e. ‘‘turn right ten degrees’’, or
- The aircraft is asked to report its heading so that the controller can estimate drift and then calculate the new heading required in absolute terms i.e. ‘‘turn right heading 010’’.

Thus an aircraft tracking 090 but experiencing a strong southerly wind may be heading 120. If the controller wants the aircraft to move ten degrees to the left of track (a new track of 080) the heading required is 110 which requires opening the elastic vector twenty degrees to the right of the current track (090) in order to achieve a left turn of ten degrees. This is not compatible with safe operations in a busy air traffic environment.

The design of graphical tools should map onto the users own mental model. Care must be taken to understand the nature of the existing mental model when representing it graphically.

20.10 Conflict Detection.

Conflict detection is a task performed by both Planner and Executive. In the AS09 scenario the conflict detection task of the Planner was automated with the results being shown as points on an abstract display; the Conflict Display(see Appendix A for description of display logic).

This approach raises three areas requiring deeper investigation.

1. What is the effect on the Planner's knowledge of the sectors activity (the 'picture') when the conflict search task is automated? How is the ability to regulate the sector activity affected?

2. What is the effect of using abstract displays that do not mimic or complement the controllers own mental modelling? Do they increase the distancing effect that was becoming apparent in AS09 and described as ''..... but I don't know what's going on''.

3. What is the effect of using very focused 'prompts' to trigger action from the controller? The triangular symbols on the conflict display demand intervention from the controller and the task can tend rapidly towards one of removing triangles rather than resolving conflicts. Does this type of 'prompt' increase the distancing effect even though it is trying to utilise the skill resource of the controller more efficiently.

Information display becomes central in determining the role of the controller within these future scenarios, the effects must be fully researched in both small experimental environments and large realistic simulations before implementation is considered.

21. CONCLUSIONS

AS09 was a limited, 'first-look' prototyping exercises at a complex scenario that involved a thorough re-working of current ATC procedures and working practises. The results should be considered as being more of guidance to further work rather than being absolutely conclusive in their own right. Thus the conclusions drawn are of a more general nature pointing the way to further more in-depth analysis. Comprehensive cost-effectiveness, capacity and safety analysis were outside the scope of this initial study.

Recalling the study objectives:

To define and investigate a scenario based on the assumption that integrating 4-D FMS generated data into real-time ATC, through the use of datalink communications, could provide the potential to increase airspace capacity and therefore :

Main Objective 1: ***to evaluate what the operational constraints of such a concept could be.***

- The experiments indicated that if 4-D FMS Data is used to create a pre-planned environment where:

    - conflicts are detected and resolved 10-25 minutes or more before they occur,
    - the separation standards applied are the same as for real-time radar control , and
    - the airspace is divided into sectors at the Planner level all the way down the system to the functional layer.

  then a consequence is that the behaviour of Executives and Pilots will be more constrained than at present. The system will be less responsive to short notice requests than present systems. Flexibility can be maintained if requests are anticipated.

- The experiments, based on the simplified RUHR/OLNO sector with simplified procedures, allowed the Planner to manage a throughput of 150 aircraft in one hour such that the Planner's tasks were not very demanding, and there were very few occasions where the Executive had to intervene. This represented an increase in airspace throughput of approximately 70% over peak levels. The indications are that there is a potential for a large increase in throughput but that this potential is dependant on the results of further research on human factors and safety issues.

Main Objective 2: ***to understand the possible controller roles which could result from the implementation of these technologies.***

- The study indicated that applying radar type separations the Planner could achieve increased traffic levels, and increased complexity in the traffic pattern but that it then became extremely difficult for the Executive controller to intervene and maintain safety, when necessary, in real-time. This was not made easier by dividing the sector traffic into two populations, 'Concerned' and 'Not-concerned' because the focus of the two groups was not the same focus as needed at that time by the Executive .

Thus the Executive role tended to become one of a 'monitor' and difficulty was experienced when rapid intervention on unplanned situations was required.

- The study identified that it would appear possible to isolate the decision making aspect of the controllers task from the control aspect when very accurate 'tools' such as the AS09 version of MTCA are used. This indicates that there could be a fine balance between versions of a 'tool' that either make it too inaccurate to use or so accurate that it changes the role of the controller.

- The Planner role became detached from the real-time situation, and tended to be 'system driven' by being focused on problem solving rather than overall sector control. 'Control by exception' would probably mean passing control to the system.

Secondary objective: *to understand the controllers HMI requirements.*

The study provided the following conclusions:

- In heavy traffic conditions when an unplanned event occurred the Executive needed some graphical tool to help in rapidly identifying the potential conflicting traffic. The Executive was very exposed when an aircraft went outside the limits of the MTCA protection, i.e. it left its plan. The next level of support is STCA (Short Term Conflict Alert) but this had a limited range which left a gap in the support provided.

- The 'elastic vector' tool has the potential to be dangerous in that it does not have knowledge of drift, i.e. it is a 'track' tool not a heading tool. As controllers usually use headings the values read off the elastic vector will not be appropriate and in busy conditions confusion could occur. If track is used to control aircraft in one centre but not in the adjacent one then pilots could become confused when crossing centre boundaries.

- Display logic, such as in the Conflict Display, which is either an abstraction of reality or uses 'prompts' to focus individual events needs positive research to allow a better understanding of the possible distancing effect.

- The HIPS Tool was considered appropriate for visualising 'aircraft to aircraft' and 'aircraft to airspace' problems especially in the direct routes ('free flight' like) scenario where visualising conflicts was more difficult because of the random nature of the traffic distribution. There were problems with some of the logic for manipulating trajectories which requires additional development.

General conclusion on the study process.

It was identified that there was a need to be able to simulate real-world disturbances in order to be able to answer questions such as,:

- "what happens if a large Cumulo Nimbus system develops rapidly",
- "what happens if an airport closes and aircraft have to divert and start holding en-route",
- "what happens if an aircraft has a sudden loss of pressurisation and needs rapid descent".

Most importantly,
- "what are the limits of this system",
- "what happens when it reaches its limits"

Prototyping is a very powerful tool for refinement of ideas but to understand all the essential aspects of a systems behaviour, especially the safety issues, more depth of study is required than can be achieved within the prototyping process. Understanding the system's behaviour under predictable, extreme and unusual conditions is an essential part of systems design. The participating controllers appreciated this and wanted more information.

22. RECOMMENDATIONS.

The objective of such studies is to refine ideas and to identify the real questions which then require more detailed and scientific analysis in order to be answered. Many questions have been posed within the body of the Note, and have been left there, unanswered, in order to keep them in context. It has been possible to identify certain specific areas from the text which have consequently been raised as Conclusions. However, under Recommendations, it is more appropriate to return to a higher level of objectives and make recommendations which, if satisfied, will allow research into ATC Systems development to identify and then answer the key questions.

The recommendations emerging from the study are;

The Study Process

1. A realistic simulation platform is needed to allow full, objective analysis of the impact of new technologies and computer assistance on the capacity and safety of the resultant system.

2. Cost-effectiveness, capacity and safety issues must be addressed as early as possible when exploring system developments.

The role of the Controller

3. More objective-research is urgently needed to qualify and quantify the effect of increasing levels of automation on the role of the controller. Special reference should be made to understanding the effect on controllers mental modelling of 'prompts', abstract displays and graphical tools.

23. FURTHER WORK ON FMS INTEGRATION.

In respect of further studies into the use of FMS data to create a pre-planned ATC environment there are many areas raised within the body of the Note and in the Conclusions that should be taken into account. Two specific areas which warrant closer attention are;

1. To allow the system to be more flexible Planner level separation standards should allow for a level of deviation on the trajectory of each aircraft for;

- time along route,
- turning points, and
- climbing or descending phases.
  (AS09 used a simple set of 5 miles and 1 flight level).

2. To reduce the inflexibility caused by sector boundary co-ordination investigate dividing Planner sectors at a graphical level but not all the way down to the functional level of the system.

24. ENDNOTE.

The AS09 study involved the definition of a complex scenario involving the use of 4D-FMS data and datalink. It then attempted to answer the question: Is this organisation realistic and feasible?

The results obtained have provided useful information on clarifying certain issues and identifying particular areas requiring further study. It is not possible, however, to provide definitive answers from this type of prototyping exercise.

AS09 went in to the world of ATC systems design where it was involved with more than just a collection of individual isolated components. The understanding of the behaviour of computer assisted ATC systems is still at an early stage of development. It should be an objective of all involved in the design, development and implementation of these new generation systems that they are developed with a full understanding of their capabilities and limitations.

In this respect it is always useful to involve system users in the early stages of the design process. The Maastricht controllers were very appreciative of this participation because it is not usual for them to be so involved so early. Their response was very positive even if AS09 seemed detached from the real world of Maastricht operations. The inclusion of users at a prototyping stage has another positive aspect in that it concentrates the mind of the researchers through the need to address often difficult questions.

What needs to be kept in focus is that often new technologies demand or create radical shifts in culture and working methods. The challenge is in trying to anticipate and design-in the changes and thus ensure integrity and safety.

While nobody expects that the future ATM system in Europe will contain all of the ideas proposed in AS09, the exercise and subsequent enhanced studies can contribute to the definition process of what is operationally reasonable. It can also contribute to clarifying what can be expected in terms of capacity and efficiency benefits.

Acknowledgements are due to Darren Smith for his efforts in transcribing a loose, verbal description into a software application, and to Claus Meier and

Patrick Petitfils, both from Maastricht Operations, for being so positive in their analysis and participation.

If this document provokes questions, criticism or comments please communicate them to either Nigel Makins (331) 69887471 (mak@eurocontrol.fr) or Alan Drew (331) 69887514 (dre@eurocontrol.fr).

APPENDIX A. CONFLICT DETECTION, DISPLAY AND RESOLUTION.

1 Conflict Detection -Medium Term Conflict Alert (MTCA)

The MTCA function was based on predicting the trajectory of each aircraft through the subject airspace and estimating the 3-dimensional position every 10 seconds.
The future predicted positions were then compared to detect where the separation standards would be infringed.
The separation standards applied to these future positions were,

5 miles lateral separation, or
I flight level vertical (1000or 2000 feet as appropriate),

If any pair of aircraft were predicted to infringe those standards then a ‘conflict’ was flagged to the Planner and Executive controllers responsible for the section of airspace where the conflict was predicted to commence.

2 Conflict Display.

Each conflict was made known to the controllers through placing a triangular symbol on a graphic display called a Conflict Display.
(The Conflict Display is based on a design used in various other simulations, including ODID IV, but modified to take into account the requirements of the AS09 scenario).

The display is a graph of time against distance.
Time is measured forward from current time.
Distance is the minimum predicted distance between the two aircraft concerned during the conflict period.

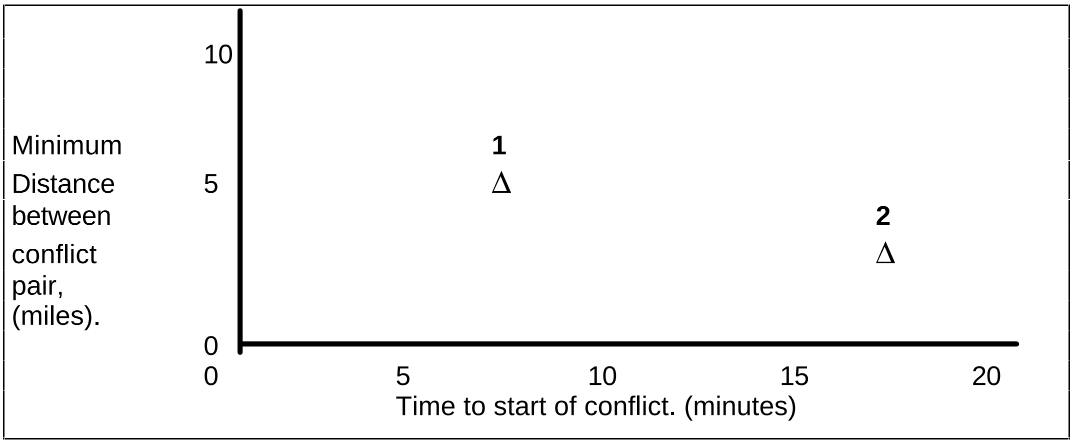


Fig i. Conflict Display

A conflict is denoted by a triangle which is placed at the intercept of two lines,

- the time line denoting the start of conflict, i.e. the time when the prescribed separation is first lost,
- the distance line being the minimum predicted distance, which will occur at some other time after the start of conflict.

(NOTE. This is a change to the logic used within the ODID Functionality. There the triangular symbol was situated at the time that minimum separation was predicted to occur and a time line for conflict duration was drawn horizontally through this symbol. The reason for shifting the symbol to the start of conflict time was to

- allow for the eventuality of conflicts between slowly converging aircraft, where separation would be lost several minutes before minimum separation. (These situations will become more frequent in a direct route airspace organisation.) and

- to provide the controller with a focal point on where the separation is lost. The time of minimum distance and duration are both background information which mayor may not be of use in formulating a resolution.

The reason for removing the duration line was to reduce clutter, very apparent when several slowly converging conflicts were displayed.

To illustrate the display logic,

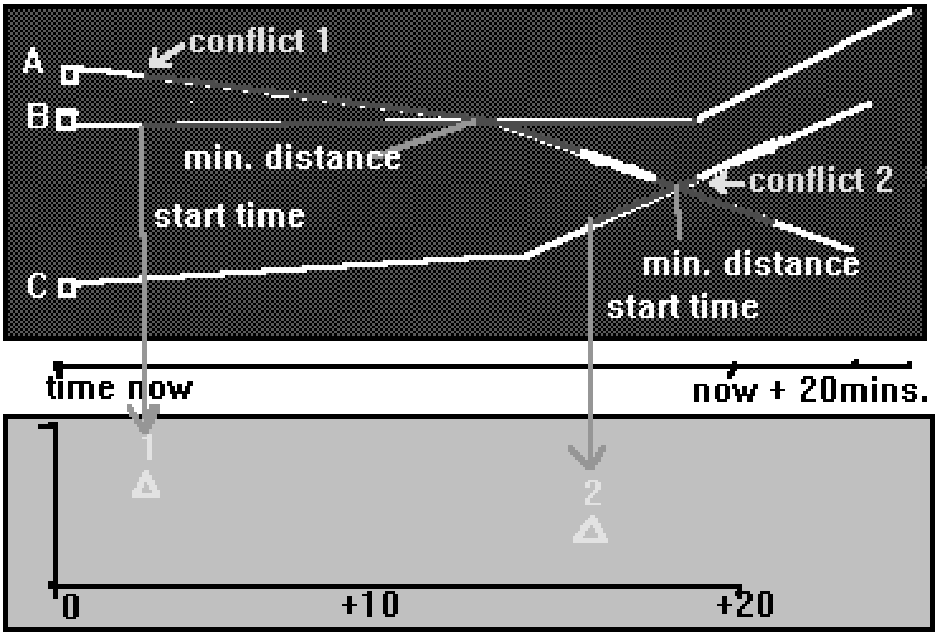


Fig ii. Conflict display logic

In the above example the conflict No. 1 is outside the domain of the Planner controller. The expectation is that this conflict should have been resolved earlier by the Planner. Thus something has not been done according to the system expectations. However the system must still be able to cope with the unexpected situations. The Conflict Display will not include the graphic details of the trajectories. It is a simple graph providing access to details of the detected conflict.

To access details of a conflict the Left Mouse button is used to click on a triangle. The flight legs and flight plan labels of the two aircraft concerned open up in the radar window. Any other conflicts on either flight leg show up as red zones further along the trajectories. The information provided at this point is intended to allow a choice of which aircraft should be manoeuvred to resolve the conflict.

3 Conflict Resolution.

To manoeuvre an aircraft requires its trajectory to be modified, e.g. route, profile or time along route. This can be achieved by making one of the involved aircraft the focus of the trajectory editor, which for AS09 was a modified version of HIPS (see References for full functional description of HIPS).

To make an aircraft the subject of the HIPS display requires a click with the Left mouse button on the callsign field. This provided viewing rights but not editing rights. To edit the trajectory required a click with the right button on the callsign field of the chosen aircraft. (This process was short circuited slightly by automatically inserting one of the two aircraft into HIPS when clicking on the triangular symbol).

The reason for the second click to gain edit rights was two-fold,

- to ensure that edit rights were available, which was a function of having both communication rights and checking that the aircraft was not at that time under tactical control and,
- to block any automatically triggered events such as inter sector co-ordination. If the system is being used to support the controllers then the controllers need to keep the system informed of their actions and in some cases their potential actions.

The modification(s) to the trajectory/ies can be datalinked directly from the HIPS function to the aircraft by selecting ‘SEND’ from the HIPS display buttons.
The resulting sets of 4-D constraint points defined by Latitude, Longitude, altitude and time would be communicated directly to the affected aircraft’s cockpit where the pilot could examine them and input them to the FMS if agreed. (This on-board process was not investigated, a simple accept from each aircraft for each new set of points was all that was included at this stage of development).

An ‘accept’ message would be assumed to be downlinked to the ground thus causing the ground flight plan data base to be updated and thus resolving the conflict which triggered the whole process.

By providing a modified Conflict Display to the Executive controller, i.e. with a time line of only 10 minutes in to the future, if the Planner completed the above process before the start of conflict time reached this ten minute threshold, the Executive did not see the conflict triangle at all.

APPENDIX B. TRAJECTORY MANAGEMENT

1 Examining the options

The management of the trajectory data was an issue that was central to the ability to integrate the data in to real-time operations.

The main questions were,

- how far into the future could the trajectory be predicted and still remain usable in terms of consistency and accuracy?
- how far into the future could traffic situations be predicted and remain complete enough, in content and complexity, and still be relevant to the real-time operation?
- who (which control function), would have access to this data?
- who would have control over this data and the rights to modify it?
- who would communicate the trajectory data, with the pilots and under what constraints and procedures?

2. Option 1 (The traditional organisation).

An initial approach was to consider a traditional type of organisation that would map easily and closely to current control procedures and would thus provide answers to the questions posed above.

This traditional type of organisation is based on a Planner

- receiving trajectory information ten minutes before sector entry,
- examining the whole route through the sector at the same time
- deciding whether there are problems within that route that could be resolved by altering entry conditions,
- either accepting or modifying the entry conditions
- when the aircraft enters the sector all communications are responsibility of the Executive controller.

This one-shot approach was rejected at this stage because it was considered that it did not exploit the full potential of this new type of data. The reasons were:

- the one shot view of a trajectory valid from 10 to 30 or more minutes into the future, depending on the transit time for the sector, did not take into account the reducing quality of the predictive information if meteorological conditions were not very stable. The prediction being used would have been prepared by the pilot some time before the Planner started to use it, thus it would be based on forecast wind conditions 40 to 60 minutes in advance of the aircraft.

- the task of examining trajectories, modifying them and negotiating changes with pilots, is not the type of control action that an Executive controller should be occupied with. *The role of the executive is to maintain safety in the sector in real-time*. In sectors of increased capacity this will require concentrating and focusing on the traffic situation and being immediately available to respond to alerts

- maintaining the Executive position as sole communicator would require constant checks for approval whenever the Planner wished to make a datalink communication. This would slow down the process and place an extra task on the Executive and Planner. This also meant that if a Planner sector became decomposed into several Executive sectors there would be a search task for the relevant Executive.

- the one shot view would be using incomplete traffic information for the exit area of the sector, because other aircraft entering around that exit point would not be informed to the Planner until ten minutes before their sector entry.

An example to illustrate,

TIME	EVENT
10.00	receive an estimate on aircraft A - entry time 10.10 - exit time 10.45 FL 310, This creates a conflict at time 1035 in the exit area with an a/c B. The conflict can be resolved if Planner gives entry clearance to a/c A at FL 280.
10.05	A/c B has recalculated fuel burn and asks for new cruise level of FL 330 to be implemented at time10.30.
10.35	An estimate on an a/c C is received. The entry level is FL 280, C is entering at the point where a/c A will be exiting. This creates a conflict between C and A (now flying at 280 because of the earlier prediction of a conflict with a/c B), Thus a/c C receives a new clearance at FL260 because it is too heavy to climb to FL 310
The result	FL 310 is left vacant.

What has happened is that by examining the same future time zone but on different occasions, for different reasons and with differing data, there becomes a tendency for actions taken to be either cancelled out by later events or make later events more complex.

A/c A was initially descended because of a/c B, but because a/c B later asked for climb the earlier descent of A not only became pointless but it actually created a new conflict with a/c C.

An alternative action by Planners is to ignore situations so far into the future and leave them to the Executive to resolve, the uncertainty about a situation can be too large to allow effective decisions. This puts the situation to the Executive to resolve in real-time. The objective of AS09 was to see if the influence of planning traffic situations could be more widespread through a sector and therefore contain the workload of the Executive as real-time traffic levels increase.

It was therefore considered that an innovative approach would be more appropriate in understanding the possibilities and constraints of utilising accurate FMS data. If airspace capacity is to be increased then the control actions should be made as efficient as possible.

The organisation that was developed to address the above stated problem areas was not complete in itself, and was not intended to be a final model. It was intended as vehicle to provide information on what direction to take to find a workable, safe, efficient and cost-effective model.

3. Option 2 (The division of a trajectory into different time zones),

The preferred option was to divide the trajectory into areas of responsibility depending on time.

A. The different time zones

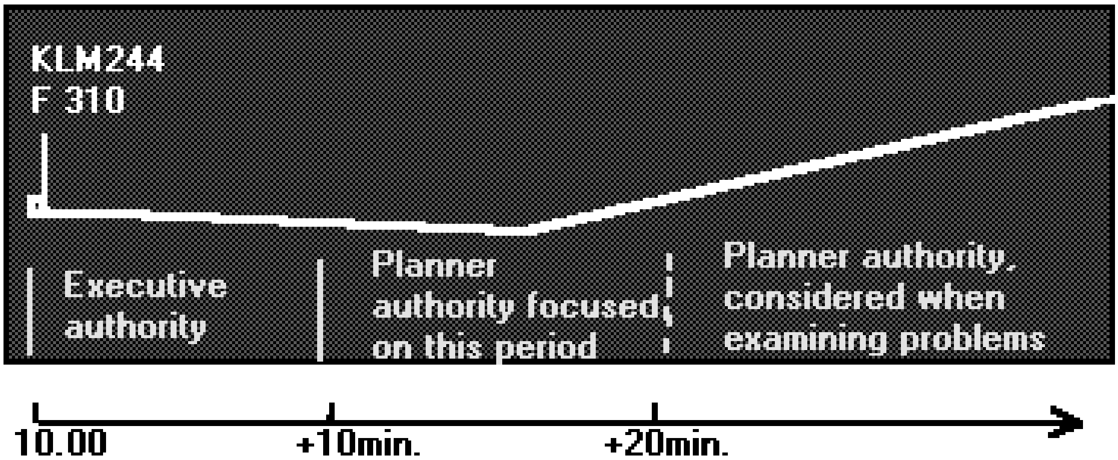


Fig i. Division of responsibility

The Executive is responsible for the situation in real-time and is provided with full information on all trajectories for the next ten minutes. The Planner is not allowed to make changes that will come into effect within less than ten minutes. This is in order to provide the Executive with a stable picture of the traffic situation.
The Planner has authority to change any trajectory in the period more than ten minutes ahead of the aircraft (providing the pilot is consulted).

B. A conflict occurring more than 20 minutes ahead would not be displayed in the Conflict Display and would not be apparent to the Planner.

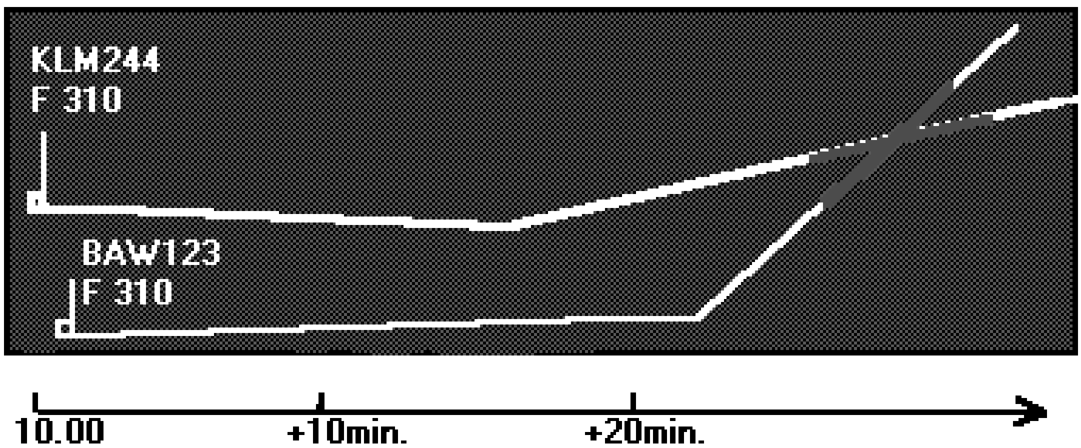


Fig. ii. Example of a conflict that would not be shown in Conflict Display.

Events beyond twenty minutes ahead of the aircraft are not signalled in the conflict display, but are shown on the flight legs if they are opened. This is to help prevent unnecessary manoeuvres determined from examining an incomplete view of the future traffic situation. Aircraft taking off from adjacent airports will take 10 to 15 minutes to arrive in these upper airspace levels, above flight level 245, and these should be taken into account where possible.

C. A conflict less than 20 minutes away would be apparent in the Conflict Display and when the Planner accessed the details of the conflict, by clicking on the conflict symbol, other conflicts beyond 20 minutes would be displayed as well.

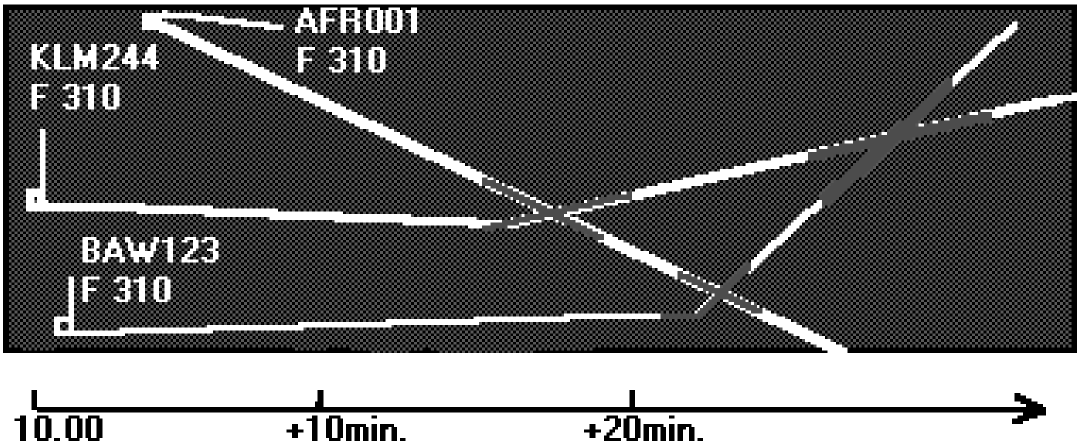


Fig. iii. Conflicts occurring less than 20 minutes away shown in Conflict Display.

The AFR001 - KLM244 conflict would be in the Conflict Display, but not the other two conflicts. The Planner would see the other two conflicts in this more complex picture on selecting AFR-KLM conflict from the Conflict Display..

D. To simplify the explanation consider that the BAW does not exist and thus there is only the AFR - KLM conflict to be resolved. This could be achieved by descending the KLM to 290 before the conflict occurs. Thus a profile view of this is as below..

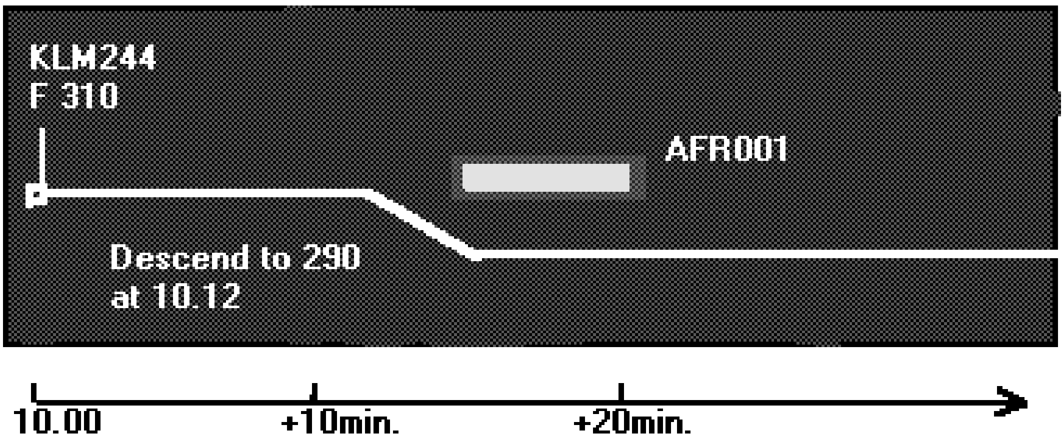


Fig.iv. Conflict resolution action has been taken.

If the KLM is descended at 10.10 or later then the Planner can communicate this solution directly to the KLM pilot and agree the change without informing the Executive, because the action will take effect more than 10 minutes into the future.

E. The information that the Executive will see, as soon as the descent is agreed between Planner and pilot is as below.

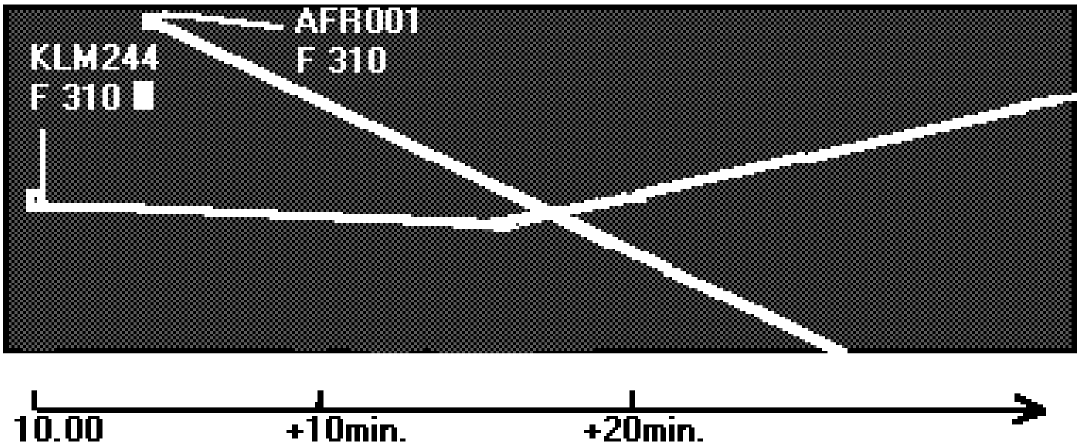


Fig.v. Information displayed to the Executive on the conflict resolution.

F. As the descent point enters into the Executive zone of responsibility, the resolution has been fixed, the Executive has full knowledge of the time and type of manoeuvre and two minutes before descent starts a warning will be given in the KLM label that descent will be starting. The CFL field shows the 29 but without a descent arrow.

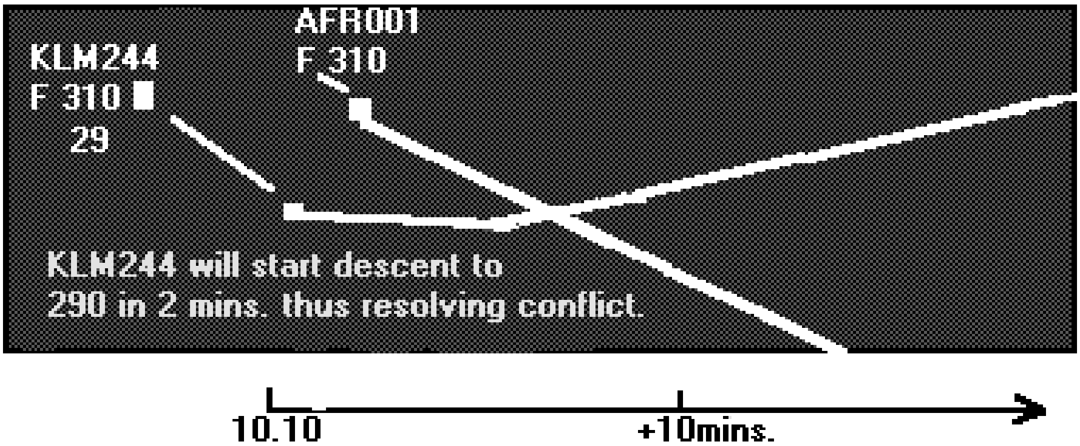


Fig.vi. The resolution manoeuvre.

The Planner is now considering and resolving situations further downstream, beyond time 10.20.
The Executive situation is stable and the conflict has been resolved to the satisfaction of the pilot.

By using this type of organisation it was invisible to the Planner which Executive sector was involved.

If the Planner is considered in terms of smoothing out trajectories ahead of the aircraft it is not too difficult to imagine that this is similar in effect to the situation where all aircraft, by chance have requested conflict free profiles, and thus the Executive has been left in the position of ensuring that all goes according to plan.

The characteristics of the AS09 organisation thus became orientated around;

- the conflict detection and resolution functionality,

- the management of the trajectory data,
- the controller-pilot negotiation process, and
- the channels of communication needed to complete this task.

Thus the main characteristics determined at this stage were,

- the Planner was responsible for establishing a ‘problem-free’ plan for all datalink equipped aircraft within his sector, (based on a Medium Term Conflict Alert (MTCA) function of automatically comparing flight planned trajectories, see section on Conflict Detection).

- the Planner had authority to modify any condition on a trajectory, in agreement with the pilot, provided that the modification could be implemented at least ten minutes ahead of the aircraft.

- the Executive always knew what was happening during the next ten minutes, this time frame was protected to maintain a stable real-time environment.

- aircraft entering the AS09 airspace had to provide more than 10 minutes notice to enable a conflict search to be performed and any necessary re-planning to be actioned by the Planner,

- the Planner’s task became focused on, but not restricted to, resolving system detected problems in the time period 10 to 20 minutes ahead of the aircraft. This state was rolling in a dynamic sense. The focus on this time period was achieved by using a Conflict Display as an access to the details of system detected conflicts. This display only contained conflicts occurring in the next 20 mins, and was updated every 30 seconds.(see fig. 3 of Controller Screens for detail).
  This was an attempt to control the degradation of data beyond that time caused by unstable met. conditions and to consider traffic situations with a more complete and stable data set. not presenting details of system detected conflicts to the planner, through the Conflict Display, until 20 minutes before they were predicted to start.

- the Planner had sole authority to communicate with an aircraft via datalink, and thus did not require to seek Executive control permission to make transmissions. (Communicating with the pilot, via datalink, is the most secure way of transferring the large amounts of data attached to trajectory management.)

- the Executive had sole authority to communicate with the aircraft using r/t, this takes into account the often immediate, time critical nature of the Executive task.

APPENDIX C. AUTOMATED INTER-SECTOR CO-ORDINATION PROCEDURE.

The transfer of data on individual aircraft from one sector to another needs to be governed by procedures which determine what data is passed, when it is passed, and what are the restrictions applicable to both parties for the period between the initial agreement and the time when the aircraft crosses the boundary in question.

In the AS09 scenario an objective was to understand the effects of automating this transfer of information on individual aircraft from one sector to the next. The SYSCO Documentation was used as a base model for the procedures, although these were adapted and simplified.

The main aspects of the model used in AS09 were,

- The trajectory data and boundary conditions were available to the receiving sector well in advance of any agreement, i.e. a common data base.
- The Planner sector was comprised of two or more Executive sectors,
- This process only applied to the crossing of a Planner sector boundary.
- The boundary conditions agreement was triggered 20 minutes before an aircraft crossed the Planner boundary.
- The process was not a transfer of data but an agreement on boundary conditions with attached rights to access the data to modify it and the right to communicate with the aircraft concerned.
- The agreement process did not require Planner action if certain simple conditions were met.

The trigger for the process was 20 minutes before sector exit time. At that time a set of tests were posed.

The tests applied for the giving sector were,

First test. Does a conflict exist on the trajectory of the subject aircraft up to the boundary?

Second test. Does a conflict, involving an aircraft exiting the same Planner sector, exist on the trajectory during the first five minutes into the next sector?

If the answer to either of the above questions was YES then the process was stopped and a message was placed in the Co-ordination Out Window of the giving sector. If the answer was NO then the process continued to the next test.

If the answer to both questions was NO then a message is sent to the next sector to trigger the final parts of the process.

Third test. The test applied in the receiving sector was; Does a conflict exist on the subject trajectory for the time up to five minutes into the receiving sector involving an aircraft not the subject of an agreement with the giving sector?

If the answer to this was YES then the process was stopped and a message was placed in the Co-ordination In Window of the receiving sector.

If the answer to this was NO then a message was sent back to the giving sector :

- agreeing the boundary conditions,
- allowing transfer of rights of access to modify the trajectory beyond the boundary state, and
- allowing direct access for the receiving sector Planner to communicate directly with the pilot via datalink.

The reason for not assuming a common data base for the conflict search function of this agreement process was because of the possibility of the receiving Planner being involved in the process of negotiating a modification to the trajectory of another aircraft. This negotiation process, involving the pilot, can take up to 5 or even more minutes to complete. It was considered more reasonable to account for this uncertainty by requiring an independent search in the two concerned sectors, thus reducing the need for ground-ground messages

If this agreement process was stopped in the receiving sector because a conflict had been found then a proposal for a new trajectory could be made. This would be constructed by the receiving Planner, for the inbound aircraft, and sent back to the giving Planner for his approval before any changes were communicated with the aircraft. Thus there would be a period of time where an aircraft would be following a particular trajectory, available through opening the flight leg/flight plan label, whilst another proposed trajectory was being negotiated between the two Planners. The proposal, itself, would first have to be agreed by the giving Planner and then agreed and confirmed by the pilot.

The co-ordination process can best be appreciated through visualising the process.

A. A failure of first test (Does a conflict exist on the trajectory of the subject aircraft up to the boundary?)

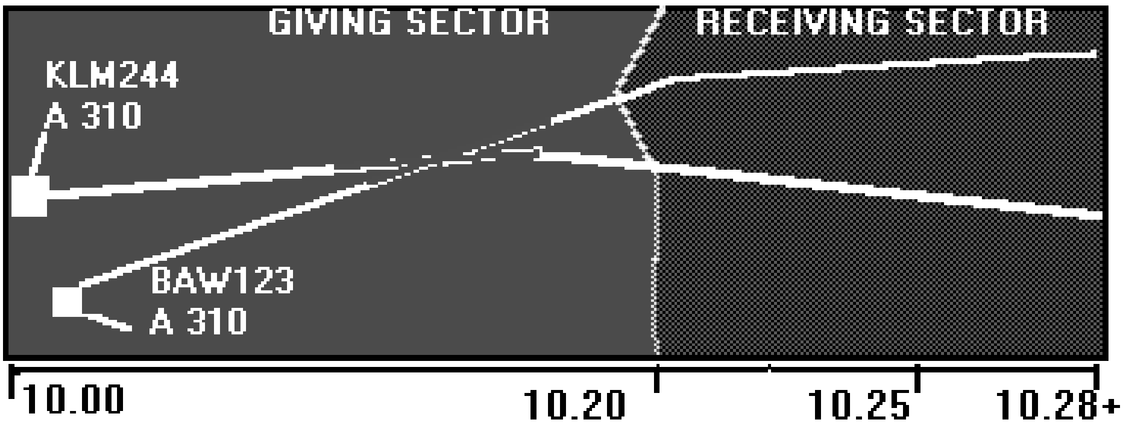


Fig.i. test 1; fail
A conflict is discovered within next 20 minutes.

B. A failure of second test. (Does a conflict, involving an aircraft exiting the same Planner sector, exist on the trajectory during the first five minutes into the next sector?)

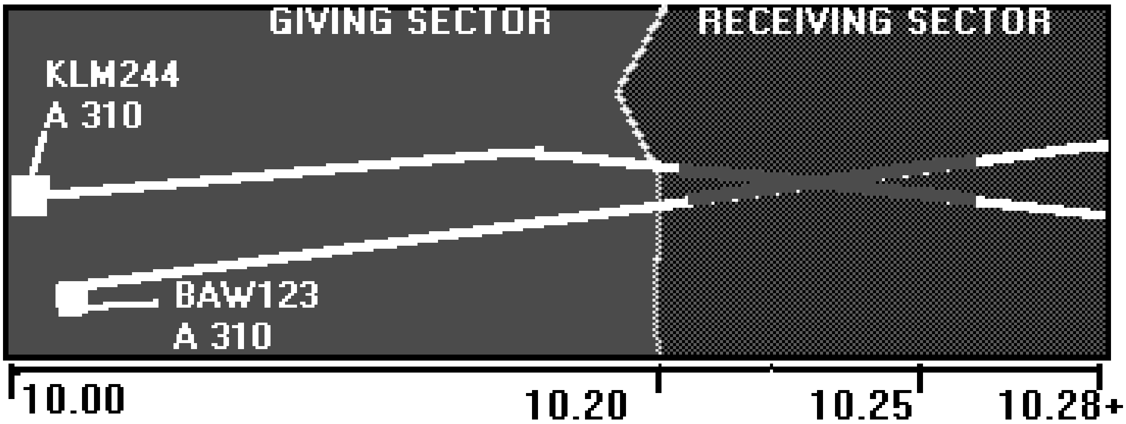


Fig.ii. Test 2; fail

A conflict is discovered within 5 minutes of next sector entry involving another aircraft exiting giving sector.

C. A pass at the second test

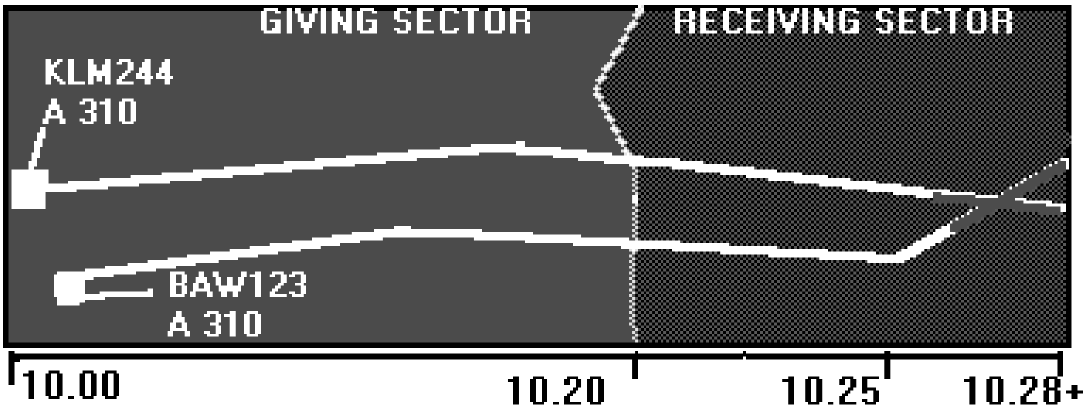


Fig.iii. Test 2; pass - the conflict is beyond 5 mins. past the sector boundary.

The conflict beyond 5 minutes into next sector is excluded from blocking process.

D. A pass at the second test.

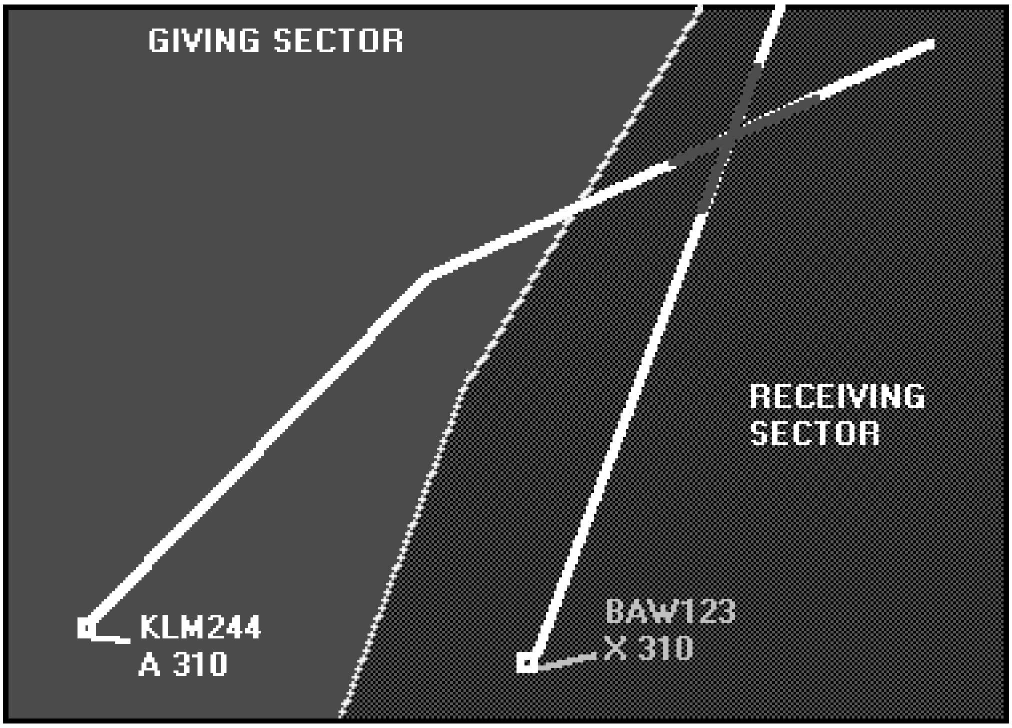


Fig iv. Test 2; pass - BAW123 is not known to the giving sector.

The conflict with BAW 123 is not found by the Giving sectors search because the BAW123 is not ‘known’ to the giving sectors conflict search database.
The questions posed here are,

- To what extent should the common data base, applicable to perhaps two or more Centres, be kept up to date with all controller actions in respect of the protracted Controller-pilot datalink negotiation process?

What are the costs attached to maintaining a fully informed central data base compared to allowing certain actions to be processed locally and then the results of those local actions informed to the central database?

E. A failure at the third test. (Does a conflict exist on the subject trajectory for the time up to five minutes into the receiving sector involving an aircraft not the subject of an agreement with the giving sector?)

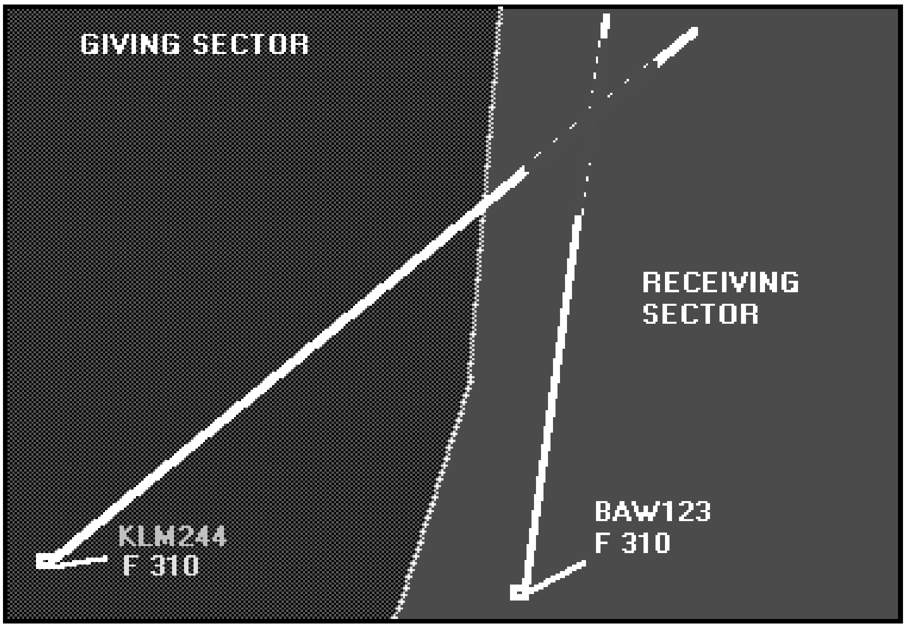


Fig v. Test 3 fail: Conflict in next sector with known aircraft

The conflict with the BAW123 is picked up within Test 3 in the Receiving sector's search. A solution can now be sought by the receiving sector Planner who has the opportunity to change the BAW123, an action not available to the giving sector Planner.

Feedback to the Controllers on co-ordination state.

The functionality described here is invisible to the Controllers if the process is completed successfully. Feedback is provided on successful completion as follows.

- If the in-bound process is completed without a test failing the receiving sector controller sees a radar label in the white co-ordinated state.

- If the outbound process is completed without a test failing then the XFL field is filled with the exit flight level, using two digits i.e. 37 = FL370.
  (An example is provided in the section on Label Functionality Appendix D).

The function is stopped when any test fails and the resulting actions are as follows.

If a test 1 or 2 fails then an exception message is displayed in the Co-ordination out window of the giving sector.

If a test 3 fails then an exception is displayed in the Co-ordination In Window of the receiving sector.

Once the exception is displayed it is the controllers task to either
- resolve the problem which has caused the exception to be raised, or,
- accept the situation..

To solve the problem requires modifying one or both of the involved aircraft's trajectories, after which the co-ordination process should be reactivated. In accepting the situation an 'accept' message is sent back to the giving sector. The receiving sector controller is then in the position of having a problem that needs to be resolved.

APPENDIX D. LABEL FUNCTIONALITY

The display of information was an issue that was central to the effective management of the sectors. In this respect the design and functioning of the radar labels requires much testing and development under high traffic levels.

The radar label has functionality that can be grouped into three categories,

- use of colour
- size of label (governed by number of fields on view)
- access to other functions

1 The full radar label.

Line 1 **CALLSIGN**
Line 2 **A** Next sector code letter
332 Actual flight level
■ marker to indicate either profile change in sector, or a Planner modification to plan

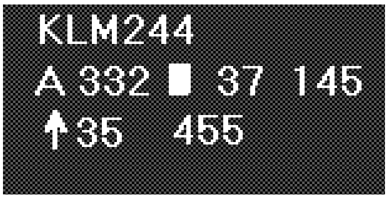


fig.i. full label.

37 Cleared flight level as a/c exits sector, displayed only when co-ordination process is complete.
145 Heading if assigned by executive.
Line 3 ↑ Tendency arrow showing either climbing or descending
35 Cleared Flight Level (Displayed 2 mins before change due to commence for a/c with agreed datalinked profile).
455 Ground Speed in knots (can be turned on or off as required) This field doubles as display of Cleared speed if applied, the Ground Speed takes precedence.

2 Use of colour

The use of colour was kept to a minimum to try to prevent a Christmas tree effect.

Callsign field

GREY	Aircraft not known to sector (this could be suppressed completely)
YELLOW	Inbound co-ordination completed, aircraft not yet released.
WHITE	Aircraft in sector (triggered when crossing sector boundary)
BLUE	For Datalinked equipped aircraft. Indicated that system would automatically send a ‘’Change to next sector’’ message if controller did not actively either block or force process. Triggered at 3 mins to sector boundary, message sent 2 minutes afterwards. When in this state no Executive orders could be input unless process blocked.
GREEN	For non-datalinked aircraft. Reminder to controller to change sector. Triggered 3 mins before sector boundary.

Rest of label.
Acted as one group for colour.

GREY	Not known to sector.
YELLOW	In-bound co-ordination process started.

	Normally this was completed in 2 or 3 seconds thus this was a very temporary state. It would stay in this state if the co-ordination process (modelled on advanced SYSCO ideas) was blocked by a conflict existing on the subject aircraft's flight plan.
WHITE	Aircraft inbound co-ordination complete.

3 Label size.

The objectives were to

1. minimise the number of fields on display to avoid label overlap problems, and
2. to design the label such that as fields were removed the fields that were left remained in a contiguous group. Thus avoiding fields becoming disassociated from main label group.

The minimum label size for an aircraft stable in cruise, with no Planner modifications, no Executive tactical control and no co-ordination is as shown.

fig.ii. minimum label

'Concerned' group label.
As one of the objectives of the exercise was to investigate segregating the sector traffic into two groups, 'Concerned' and 'Not-concerned', a label style was specified for the 'Not-concerned' group of aircraft.
As can be seen this only provided two access fields

fig.iii. 'Not-concerned'

Thus LB (Left Button) on the next sector field changed the label to the same as the normal radar label, providing normal functionality as described below.

4 Access to functions.

There was a conflict between reducing displayed information to a minimum whilst providing identifiable and logical access points to separate functions or information on each aircraft.
The minimum label (see above) only had three fields on view. This caused some difficulties in maintaining consistency in accessing all necessary information and functionality. This was not totally resolved.

- A strategy of using the Left Mouse button as much as possible was adopted.
- The middle button had no function.
- No double clicks were allowed and there were no press and hold functions (although this was not specifically prevented).
- Window management was a standard type accessible through the frame of each window.
- Menus , when opened, could be closed by clicking LB on the menu title.
- Inputs to a menu were through using the LB on the appropriate value.
- Displayed values in menus were restricted to 5 in Flight Level menu and 7 in speed menu, further values could be accessed by 'paging-up' or 'down' using active fields above and below menu choices. Scrolling was not used in order to prevent 'jumps' when screen refreshed.
- Displayed range used certain logic for determining position of the values on display as follows,

speed current or cleared speed (if appropriate) always central value.
CFL If XFL = AFL the XFL became central value of menu.
If XFL > AFL the XFL became upper value of menu.
If XFL < AFL the XFL became lower value of menu.

The active fields

Line one		
Callsign	LB	Open Dynamic Flight Leg plus Flight Plan label together.
	RB	Open ‘TRANSFER’ menu. A menu of options, the choice dependant on the aircraft state, controlling ground-ground or ground-air messages affecting the transfer of an aircraft from one sector to another.
Line two		
Next sector	LB	Opened ‘elastic vector’ to allow input of heading
indicator.	LB	(In non-conflict minimal label only) opened up standard radar label to access all functions.
AFL	LB	Opens CFL pop-up menu. (Condition: this function is transferred o the CFL field if that field is apparent. This introduces a certain level of inconsistency in access, however the CFL field is only on view if the AFL and CFL are different and if a controller wishes to modify a CFL value it is more logical to interact with the value to be changed than with one next to it.)
Line three		
CFL	LB	See AFL condition above.
G.speed	LB	Opens ‘Speed’ menu which will be in TAS or MACH depending on what value the aircraft is downlinking as part of its ADS reports. A second menu, in Mach or TAS whichever is not open initially, It is available as a menu choice available through button below speed values.

5 Label changes for a flight through the system.

The following series of labels indicate how a label could change state depending on various expected situations. The views are as seen by the same controller over a period of time.
The labels follow an aircraft (KLM 244) from a time before it is ‘known’ to the subject sector until the time it leaves when it returns to the same state as the first illustration.

1. Before any message action - unknown.

The aircraft is at flight level 280 in the climb to 350
and will exit eventually into the Amsterdam sector.

fig.iv. label unknown.

2. Co-ordination message has been received but a conflict, within 5 minutes of the sector boundary and caused by an aircraft known only to the giving sector, has blocked the process. This state will also generate a message in the Co-ordination-in Window of the Planner. The label will stay in this state until

fig v. label awaiting co-ordination.

the Planner either resolves the conflict or accepts the conditions and thus forces the co-ordination process to be completed.

KLM 244 is now passing 295.

3. Co-ordination has been completed. The boundary conditions are agreed in terms of position, altitude and time. The ability to communicate directly to the pilot via datalink is now passed to the receiving sector Planner.

KLM 244 not yet in sector, passing 317.

fig.vi. co-ordinated label

4. A larger Flight Plan label can be accessed at any time on any aircraft. This respects the colour state of the radar label allowing access to all functionality. It has priority over other graphic features, and is displayed simultaneously with the Flight Leg of the aircraft.
Line four shows aircraft type , departure point and destination.
Line five shows aircraft derived data that would be available via an ADS datalink function. It shows aircraft speed, heading and rate of vertical change.
NOTE. For non-datalink a/c the black background is changed to blue.

fig.vii. flightplan label

KLM244 is a B737 routing Rome to Amsterdam, requesting only 330 for a cruise level.
Currently cruising at mach 78, heading 243 and climbing at 4,300 ft/min.

5. When KLM 244 enters the sector, having received a change frequency message from the previous sector, the callsign turns white to indicate to the Executive that the aircraft is now under his control. This is a simplified process to current procedures, not requiring an ASSUME input.

fig.vii. In-sector label

A block symbol has also appeared on line two, an indication to the Executive that this aircraft will either climb and/or descend automatically in the sector, in accordance with a profile agreed by the Planner, or the Planner has given a route or speed change to the aircraft to be executed later in the sector. The detail is available when opening the Flight Leg.

6. KLM244 has now levelled at 350, thus the CFL field has disappeared. The label also shows that sector exit co-ordination has been completed with an agreed level of 370 (this is triggered 20 minutes before sector exit).

fig.viii. co-ordination- out finished

7. The KLM244 falls within the Not-concerned' group of aircraft for the Executive and thus may be displayed with a reduced label format if required. (NB no callsign field).

fig. ix. ' Not-concerned' label

8. The Executive decides to manoeuvre the KLM244 for some reason, by using a tactical command, i.e. the flight plan data base is not updated with future intentions because they have not yet been decided. The aircraft under tactical control will have a label framed in both Executive and Planner displays. This acts as a reminder to the Executive that the aircraft is ‘off-plan’ and either must be put back on-plan or the plan must be modified.

fig.x. aircraft under tactical control

KLM244 is on a heading of 155.

9. KLM244 has now had its plan re-established and is no longer on a heading. Thus the frame has disappeared. The value 37 has also appeared in line 3 to indicate that the agreed plan includes a climb to flight level 370 which will start to be executed, automatically by the aircraft, two minutes after the value first appears. As soon as the aircraft starts climbing the climbing arrow will appear.

fig.xi. climb expected

10. KLM244 is now in the climb to 370 passing 356. No further profile changes or route or speed changes will occur within the sector, thus the white square has disappeared.

fig.xii. climb started

11. KLM 244 is also now three minutes from sector exit and the automatic 'TRANSFER' message sequence has been activated on the ground (this is automatic for Datalink equipped aircraft).

The blue colour indicates to the Executive that the automatic process has been activated and that if he needs to keep the aircraft or give tactical instructions he must first stop the process by selecting 'KEEP' from the 'TRANSFER' menu. This KEEP action will change the label state to the next illustration, otherwise after two minutes in the BLUE state the ground system will automatically transmit a signal automatically instructing the pilot to change sector frequency.

fig.xiii. automatic frequency transfer started

12. KLM 244 has been kept by the Executive for some reason and thus the callsign is the same colour as if the aircraft was not datalinked equipped. This GREEN colour is an indication to the controller that he must do something to activate a change sector sequence.

fig.xix. manual frequency transfer needed

Once a change sector frequency message has been sent, either by datalink or r/t the label will turn to a totally grey state again. The flight has left the sector and is no longer of concern to the Controller.