EXPERIMENTAL WORKING POSITION SIMULATOR TO ANALYSE, DEVELOP AND OPTIMIZE CONCEPTS FOR COMPUTER-AIDED AIR TRAFFIC MANAGEMENT

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Abstract

The development and optimization of concepts and procedures for a future, computer-based Air Traffic Management (ATM) requires a very flexible and adaptable testbed which simulates both different air traffic scenarios and the working positions of air traffic controllers with regard to different ATM functions. The designed Experimental ATM Working Position Simulator represents an interactive realtime data processing system for traffic information, planning and coordination, and is supposed to assist the air traffic controller. Different software modules are implemented to simulate air traffic scenarios, to display flight plan data and flight trajectories and to make possible the controller´s interaction with these modules. To support the controller in fulfilling its tasks, it was necessary to develop computer-based planning aids, including a (semi-)automated tool for the prediction and resolution of potential conflicts.

1 Introduction

In order to ensure the safe and efficient movement of aircraft during all phases of operation, Air Traffic Management consists of the components Air Traffic Flow Management (ATFM), Air Space Management (ASM) and the primary one Air Traffic Control (ATC). The realization of ATM functions is based on communication, navigation and surveillance systems (CNS systems), which, at present, differ in their characteristics, capabilities as well as in the way they are implemented in various parts of the world.

The current situation in air transportation is characterized by an increasing traffic volume and inhomogeneous traffic structure with different impacts on the function units of the air traffic system. Especially the ATM seems to be restrictive for a future development in the field of air transportation. The capabilities of the national ATM systems do not meet the requirements of a modern air traffic system because of the following technical shortcomings /1/:

- The implementation and propagation limitations of current line-of-sight systems and/or accuracy and reliability limitations;
- The limitations of voice communication and the lack of digital air-ground data interchange systems;
- The limitations of ground-ground data interchange (capacity and transfer rates) require a lot of coordination of ATC and the lack of digital data interchange systems (national, international) with efficient transfer protocols;
- The limitations of flight data processing systems and the visualization of flight data;
- The different stages of development of national ATC systems and the lacking harmonization between them in adjacent areas.

Apart from the shortcomings listed above, the following operational and organizational shortcomings have to be mentioned, which result from the discrepancy between the air traffic control capacity and the traffic demand:

- Airspace structure (lot of fragments, segregation of civil /military traffic, decentralized administration);
- Small control sectors (impossibility of strategic planning);
- IFR/VFR traffic mix;
- Civil/military coordination;
- The inflexible structure of ATS routes;
- High workload of air traffic controllers;
- Operational bottlenecks at the airports.

To increase the future ATM´s productivity, it will be necessary to carry out investigations concerning its technical, operational and organizational aspects. In this connection, a research project carried out at the Berlin University of Technology was aimed of developing solutions concerning different aspects of computer-aided ATM. Here, the main emphasis was put on software engineering in order to realize an interactive data processing system that takes into consideration different aspects of operational and human factor aspects of an automated complex man-machine system as well as the development of tools of automated assistance which are supposed to determine flight trajectories and to predict and solve potential conflicts. As far requirements such as safety and reproduction of future air traffic scenarios, the usage of simulation models and experimental working position simulators has proved to be necessary.

2 Concepts for a Future Computer-Aided Air Traffic Management

International Civil Aviation Organization

In 1983, the International Civil Aviation Organization Council (ICAO Council) established the "Special Committee on Future Air Navigation Systems" (FANS) having the task of studing, identifying and assessing new concepts and technology in the field of communication, navigation, surveillance and air traffic management for international civil aviation as well as making recommendations for the development and implementation of these future technologies /2/. Since air traffic scenarios differ widely in different parts of the world and will continue to do so in future, global systems have to be able to cope with a variety of traffic densities, types of aircraft, avionics sophistication, etc.. These objectives have been the guiding principles throughout the committee´s studies and are the basis for its recommendations. The committee concluded that the exploitation of satellite technologies is the only solution viable up to now that allows both to overcome the shortcomings of the present CNS-systems and to fulfill the future needs and requirements on a global basis. As new CNS-systems will bring about a closer interaction between the ground system and the airspace users before and during flight, ATM will permit a more flexible and efficient use of the airspace and thus enhance traffic safety. According to FANS, the line-of-sight systems will continue to be appropriate where their propagation limitations do not pose a problem e.g. the use of VHF communication and Secondary Surveillance Radar (SSR) in busy terminal areas. With regard to an overall optimum result, the FANS concept has thus proved to be an effective combination of satellite technology and line-of-sight systems.

In this new concept, aeronautical mobile communication for both voice and data will use satellite-relay operating in the frequency band allocated to the Aeronautical Mobile Satellite Services (AMSS). Terrestrial-based air-ground communication will remain preferable in areas of high density traffic, e.g. VHF data/voice and SSR Mode S.

For navigation, FANS developed the concept of Required Navigation Performance Capability (RNPC) in order to support area navigation environment (RNAV/RNPC) and the development of more flexible route systems. The development of the Global Navigation Satellite Systems (GNSS) such as GPS and GLONASS will facilitate the independent onboard position determination used in aircraft navigation. In terminal areas, the microwave landing system will be preferable in cases of precision approaches.

For surveillance, FANS developed the concept of Automatic Dependent Surveillance (ADS), which will to be used by air traffic services in which aircraft automatically transmit data derived from on-board navigation systems, i.e. aircraft identification, heading, weather data and three-dimensional position information. This data is used by the Air Traffic Control to present a "pseudo-radar" or alternative traffic display to the controller and will improve future ATM functions, e.g. the optimization of conflict prediction. In high density areas ADS may serve as a adjunct and/or backup for SSR. Since it is a cooperative independent surveillance it will, thereby, reduce the need of primary radar.

The following directions of change in ATM are envisaged and will have to be supported by future CNS systems:

- Improved handling and transfer of information between operators, aircraft and ATS units (AMSS, ADS);
- Extended surveillance by using data derived from airborne systems (ADS);
- Advanced ground-based data processing systems, including "pseudo-radar" display, allowing for:
    - The ability of modern aircrafts to take advantage of the improved navigation accuracy in four dimensions;
    - Improved accomodation of a flight´s preferred profile, based on the operator´s objectives;
    - Improvement in conflict detection and resolution, automated generation and transmission of conflict-free clearances and rapid adaptation to changing traffic conditions.

Combined with an improved planning, these aims of development will allow a more dynamic ATM, particulary in high density airspaces.

European Planning

In order to take the characteristics of the European region into consideration when developing and implementing CNS systems and ATM concepts, various multilateral and state organizations were founded, e.g. the European Air Navigation Planning Group (EANPG) of European ICAO members, the European Civil Aviation Conference (ECAC) and EUROCONTROL.

In 1986, the EANPG established the "Future European ATS System Concept" (FEATS) working group. FEATS activities are based on the FANS recommendations for a high density airspace (data link via VHF, SSR Mode S, AMSS, RNAV/RNPC, GNSS, ADS) and include the components of ATFM and airspace structure /3/.

The activities of EUROCONTROL in the field of development and implementation of future CNS systems, ATC, ATFM, ASM, airspace and route structure as well as human resources are summarized in the Common Medium Term Plan (CMTP), which is involved in the FEATS concept and the ECAC strategy for the European ATC Harmonization and Integration Programme (EATCHIP). The main topics arising out of the CMTP are as follows /4/:

- The introduction of monopulse SSR, SSR Mode S and ADS;
- An automated data link between airborne and ground based computers (SSR Mode S, Satcom);
- Automatic exchange of ground-ground data (Common Integrated Data Interchange (CIDIN), Aeronautical Telecommunication Network (ATN), Radar Data Distribution, ATS Telephone System);
- The ATFM function will be based on a central data bank;
- A future ATC concept using the capabilities of modern RNAV and FMS equipment;
- An extensive use of automated assistance will allow substantial increases in control capacity:
    - Compatibility between the processing systems of adjacent areas will be essential;
    - New capabilities in display techniques and computer dialogue will improve the man-machine relationship;
    - An automatic link between FMS/PMS and ATC computers on the ground will allow trajectory prediction, the accuracy of which will be consistent with the decision-making aids to be developed;
    - Artificial Intelligence and the associated specialized activities will provide controllers with assistance to make decisions.

According to the CMTP, the ATC is aimed at substantially increasing the control capacity by an extensive use of automated assistance and harmonized procedures. The key elements of any automated system are flight plan processing systems that are functionally compatible and permit flight plan data interchange. The Advanced Control Console planned will include a harmonized radar data processing and tracking system with conflict alert. The system will also require decision-making aids for trajectory evaluation and conflict resolution. It will have new input techniques and colour display systems /6/. In order to develop and assess the new operating environment, it is planned to develop methods and tools to evaluate system workload, efficiency, capacity and facilitate traffic forecasting. These will be promoted through a continuing development of the common modular simulator.

German Planning

With the intention of increasing the capability of the German ATC system and stopping it from being the limitation factor in air transportation it still is at present, the Bundesanstalt für Flugsicherung (BFS) presented the "Cooperative ATM Concept" (CATMAC) /5/ in 1990. CATMAC uses the recommendations of the FANS/FEATS concepts concerning future CNS systems with the intention of increasing the accuracy of ATC planning data and, thus, reducing the propability of conflicts in the control sector and controllers workload. CATMAC is based on coordination processes taking place between ATC, aircraft and operators, which are due to the strategic, tactical and operational planning functions and air traffic control including on-board derived data and data link systems. To reduce capacity problems in ATC, the following improvements were envisaged:

- Advanced ground-based data transmission systems, including local area networks;
- Implemenation of advanced controller workpositions (high resolution rasterscan display, colour coding, stripless system, etc.) /6/;
- Improvements in SSR technology (monopulse technique);
- Implementation of the departure and arrival coordination systems DEPCOS and ARRCOS;
- Development and implementation of a planning system for taxiing at airports;
- Improvements concerning the airspace structure and ATC procedures.

3 Concept of an Experimental Working Position Simulator for ATM

Requirements

An Experimental Working Position Simulator for future ATM functions has to be a realtime traffic information, planning and coordination system /7/, which is interactive and allows to develop and analyse solutions concerning different aspects of computer-aided ATM, e.g. ATC concepts and procedures, software engineering, artificial intelligence, human factors and traffic analysis. The system requirements defined (modular structure of the soft- and hardware, realtime and online simulation) are supposed to allow to modify and/or implement any system component. Thus, different investigations have to be carried out with regard to the man-machine interface on the one hand (e.g. type and extent of information processing and representation; interactions) and the implementation of (semi-)automated modules on the other hand, e.g. to display flight trajectory and to predict and solve conflicts. To allow the controller to participate in the information processing is, therefore, one of the most important aims that has to be achieved. It is feasible to develop, analyse and evaluate computer-based planning and control concepts/procedures that are subdivided in temporal, spatial and operational strategies by using a flexible, interactive, on-line simulation system.

Conception of the Simulator

The realization of the necessary data processings is based on the hardware environment of a local area network (LAN). Different software modules are implemented:

- Simulation of air traffic scenarios;
- Radar display;

- Display and modification module for flight plans;
- Display and modification module for flight trajectories;
- Conflict prediction and resolution;
- Instructor interface.

A research configuration typical of the Experimental Working Positions Simulator consists of three working consoles (Figure 1). In the middle, there is the console for display and modification of flight plan data with an integrated conflict warning display, which is followed by a console for display and modification of flight trajectories and in which a display representing possible conflict solutions is integrated. A third console is used as a radar display. Interactions between the controller and these consoles can be achieved by means of the keyboards and/or trackballs.

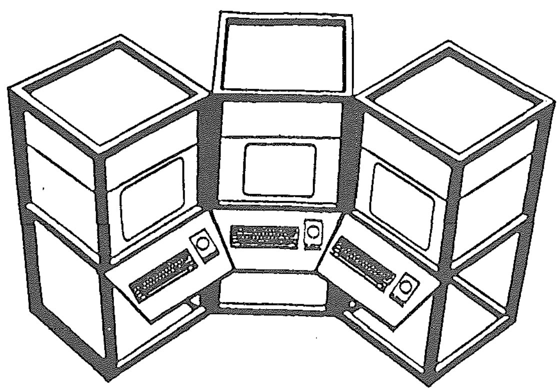

Figure 1: Configuration of the Experimental Working Position Simulator, showing: the flight trajectory console on the left-hand side, the flight plan data console in the middle and the radar display on the right-hand side.

Figure 2 shows the organization of the simulator's modules mentioned above. The flight plan data, which are processed by the air traffic simulation module, is stored in a centralized databank. Direct databank accesses are implemented into the modules used for air traffic simulation, the representation and modification of flight plan data and the interface of the instructor. The modules used for the display/modification of flight trajectories and conflict prediction have an indirect access via the module of flight plan data display. Interfaces implemented between the modules flight plan data- and trajectory modification on the one side hand and the conflict prediction and resolution on the other hand allow the output of conflict warnings and solutions to the relevant flight data processing systems. Flight data modified by controllers will be restored in the central databank and represent the updated data for new air traffic simulations. This is also true for interactions carried out by the instructor, e.g. changes in flight plan data. With regard to the evaluation and representation of results, different graphic and statistic procedures are also implemented. Graphics will be used to support a clear representation, e.g. representations of the airspace structure, which bear similarity with maps, radar display similar representations of the airspace/traffic situation, representation of the traffic load of the sector or airway.

4 Implemented Software Modules

Simulation of Air Traffic Scenarios

As far enroute traffic operations, the program system ATSAM (Air Traffic Simulation Analysis Model) /8/ allows to simulate air traffic processes in any airspace structure, for any traffic sample and any automated procedure of the future air traffic management including the air traffic control system of today.

With respect to the research to be done with the Experimental Working Position Simulator, ATSAM simulates all system elements relevant to flight operations (e.g. aircraft dynamics, aircraft control and guidance) and air traffic control (e.g. monitoring, separation) including appropriate assumptions on the influence of possible error events (such as wind, unpredicted traffic events, navigation accuracy, etc.). The flight plan data and radar information generated by the ATSAM represent the input database for the software modules as described below.

The programme system uses a database for modeling the airspace structure and organization, simulating the air traffic system processes (traffic input/generation, traffic planning/coordination, air traffic simulation) and evaluating software by means of both numerical and graphical output. Simulation runs and sample scenarios can be defined and controlled completely by data input. The ATSAM model offers three different ways to specify the traffic demand:

- Specification of fixed traffic samples (flight plan list);
- Generation of traffic according to specified distribution parameters which describe a typical traffic sample;
- Specification of conditional traffic input.

In order to work with authentical data or analyse special traffic situations, fixed samples are used (e.g. flight strip planning data recordings). In order to combine the generated traffic, with traffic samples consisting of fixed flight plans, the generation of the traffic demand usually takes place before the simulation has started. However, there are a lot of problems in ATC-related research, which require the analysis of non-typical traffic samples (e.g. to simulate critical situations).

Due to traffic planning and coordination, a flight route and the corresponding waypoints are selected from the aeronautical database (standard routes of the AIP). The economical (or optimal) altitude and speed profile is selected according to the performance of the respective aircraft type. Here fuel consumption is the parameter to be minimized. The algorithm for profile determination is based on the integrated range table concept used for flight planning in real flight operations. To refine the considered aircraft data, ATSAM includes a gene-

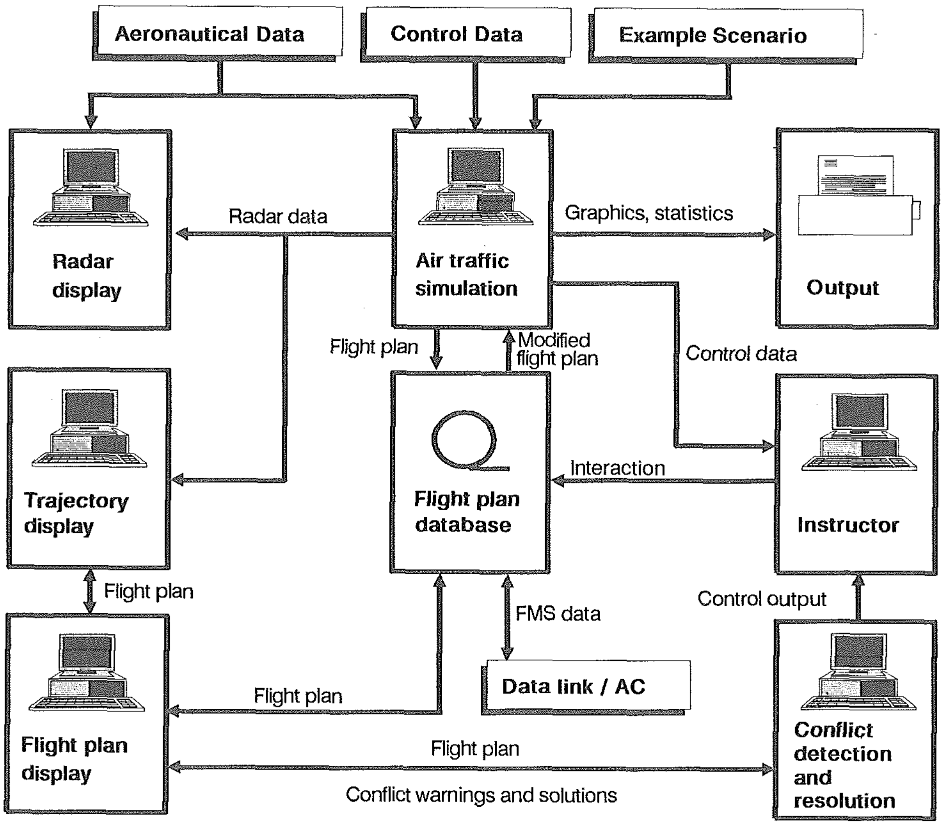

Figure 2: Organizational Concept of the Working Position Simulator

ral, abstract aircraft class model with a maximum of ten main performance classes, which, for thus part, are subdivided into a maximum of ten subclasses. The aircraft dynamics are represented by a simplified dynamic model with three control parameters (air speed, path angle, bank angle). Compared with results received from the complete differential equation of motion, the dynamic aircraft motion through the airspace is modelled in a sufficiently accurate way by this model. The simulation/integration uses a 4th-order Runge-Kutta method.

Radar Data Display

The interactive modul developed, is called MATIS (Microcomputer-based Air Traffic Information System) /9/. It has the task of visualizing the radar data generated by the air traffic simulation module and is used for supervising the consequences which result from interactions between the air traffic controller and the simulation system (Figure 3). In the course of development of planning strategies and procedures concerning future ATM tasks, the functions of MATIS are, however, only of minor importance.

MATIS supports various possibilities of representation in accordance with the man-machine interface that depends on human factors, e.g. symbols and colour coding for map displays and flight data. In order to carry out various types of displays, hierarchic structured pulldown-menues, window-technology and zoom-effects were implemented. The simulated radar display has a characteristic structure which is combined with the generated radar data, air space structure, system status information and different menues (Figure 4).

The menu-driven system allows the following settings:

- A variable representation of air space components (FIR, UIR, control sectors, airways , navigation aids, etc.);
- Options of aircraft labels, grid of coordinate system, flight level band, details;
- Representaion of aircrafts inclusive shading effects;
- Definition of colours and colour coding.

Electronic Flight Plan Data Processing

Research activities concerning a computer-based, stripless flight data processing system, be implemented in the near future, require a software module with implemented functions for the representation and planning of four dimensional flight profiles. This is the task of the program system developed, called DROPS (Dialogue-oriented Route Online Planning System) /10/. This module facilitates the representation and modification of electronic flight plan data and generated flight trajectories, respectively.

The assessment of actual and future traffic scenarios as well as the planning of conflict-free and economical trajectories determine the information the air traffic controller is shown on a monitor /11/. DROPS uses the flight plan and radar database generated by ATSAM. DROPS subdevides the electronical representation of control strip information into an alphanumeric (schedule) and graphic (trajectory) representation.

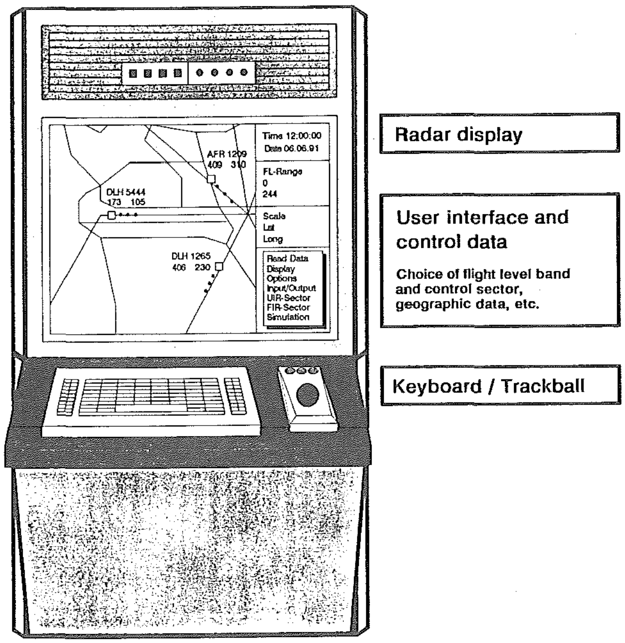

Figure 3: Working Console of Radar Data Display

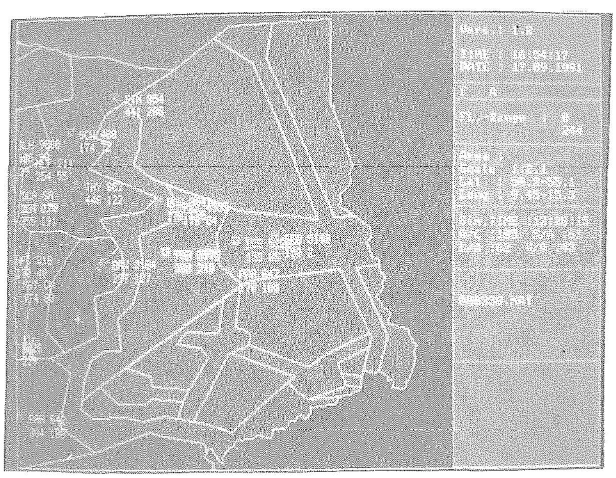

Figure 4: Display of a Control Sector with Integrated System Status Information

The flight plan data display includes information about the entry/exit time of the control sector, the internal address number of the flights, the callsign, the type of aircraft, the entry/exit point of a flight in the controlled area and a label to indicate modified flight plans (Figure 5 and Figure 6). In case the departure and/or arrival airport is outside the control sector/area, it will be represented explicitly. If the controller wants to represent flight trajectories in addition to the alphanumeric flight data shown on an additional monitor, in case of a conflict prediction, he has to choose the relevant flights by using the trackball. Those trajectories and alphanumeric data will be represented in a colour-coded manner.

The choice of the period of time examined in this research (Figure 6), e.g. peak hours of traffic, and the activation of the conflict prediction and resolution occur window-driven. The identification of a potential conflict is shown in an additional window. The critical flight plan data and trajectories are colour-coded.

The module for the representation of the flight plan data includes the following functions:

- Representation of flight plan data;
- Sort functions, e.g. for entry/exit points, entry/exit times;
- Search functions, e.g. for relevant flight plan data;
- *Options of flight plan modification* (edit-window);
- The interaction between DROPS and the conflict prediction/solution module.

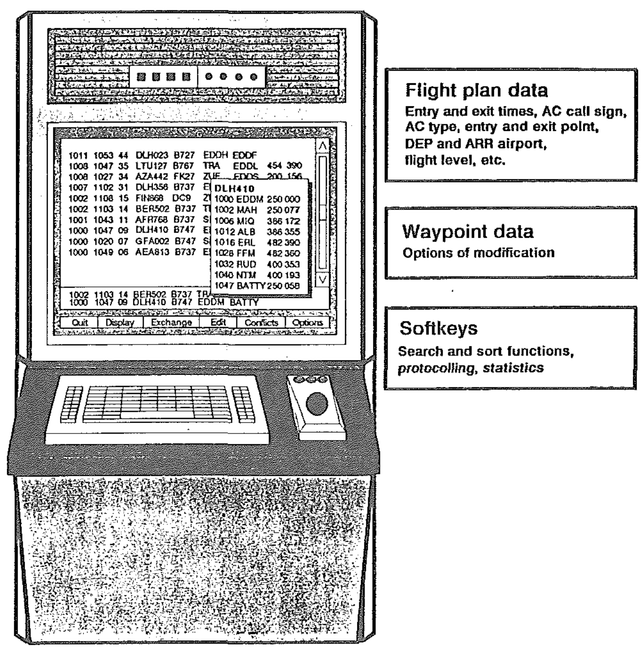

Figure 5: Working Console of Flight Plan Data Representation and Modification

Figure 7 shows the third working console, that represents and modifies flight trajectories, moreover, an additional monitor is shown which is used for conflict prediction and resolution. The display contains the vertical and lateral profile, waypoint data (waypoint code, flight level, estimated time over, speed) of the chosen flight plans (Figure 8).

window-technique and a modification performed by the (semi-)automated conflict prediction and solution module. For the respective conflict, this module gives a number of relevant solutions among which the controller can choose. Possible modifications concern the lateral/vertical profile, the estimated times over (ETO) and the speed (Figure 8).

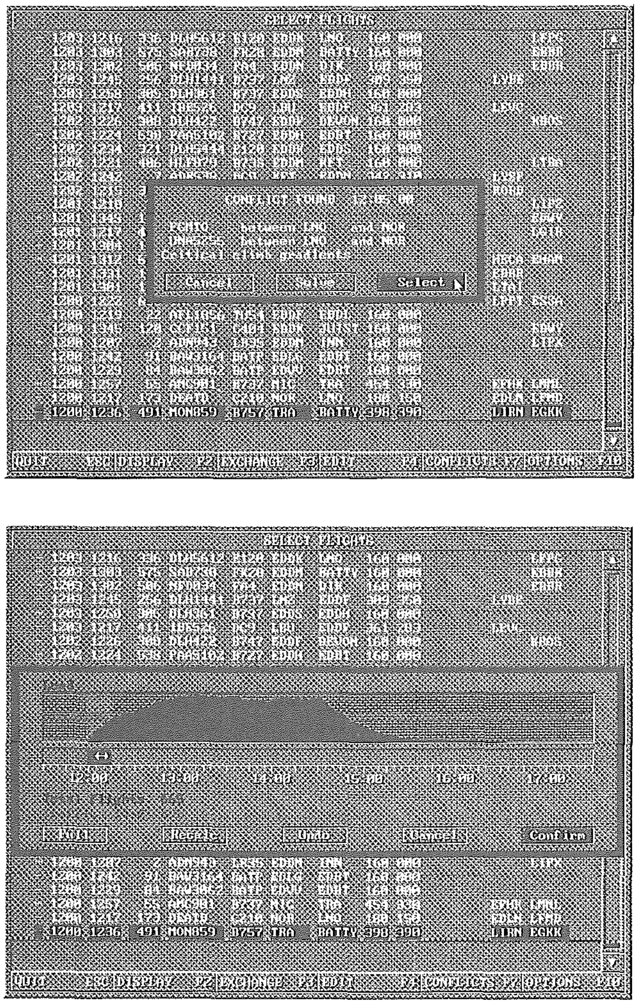

Figure 6: Representation of Flight Plan Data with Integrated Conflict Warning (above) and with Integrated Period of Time (below)

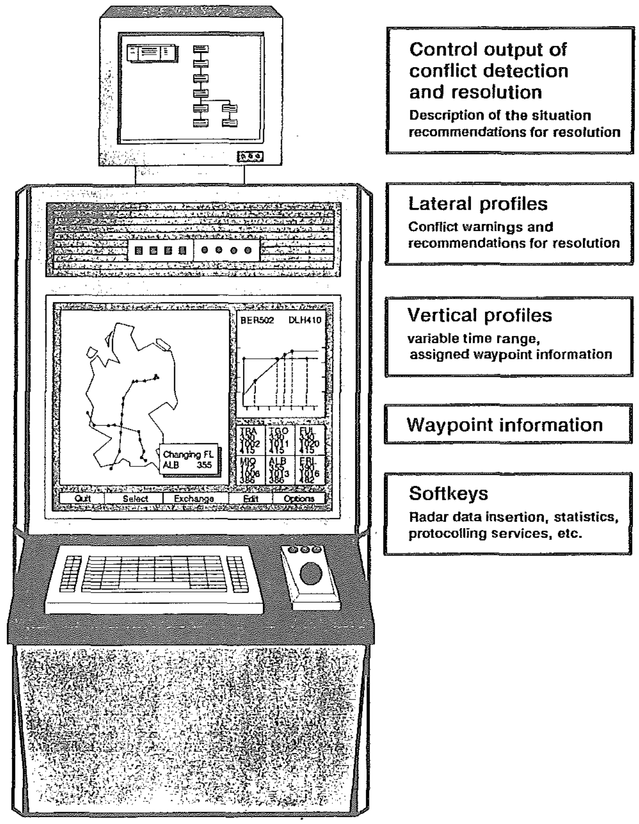

Figure 7: Working Console for Representation and Modification of Flight Trajectories

Implemented functions are as follows:

- Representation of lateral profiles;
- Representation of vertical profiles;
- Trackball-driven selection of waypoints;
- Representation of the assigned waypoint data;
- Representation of flight plan data that are correlated with radar information;
- Recommendations for the solution of conflicts;
- Trackball-driven trajectory modification;
- Various print options. e.g. for flight profiles.

The conception of the Experimental Working Position Simulator allows both a manual trackball-driven trajectory modification carried out by the air traffic controller by means of the

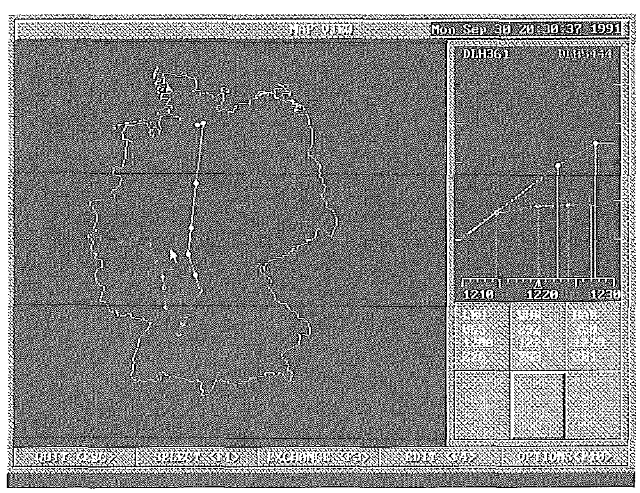

Figure 8: Trajectory Display and Waypoint Data of Two Chosen Flights

Prediction and Solution of Conflicts

In future ATM concepts the improvement of conflict prediction and resolution by means of an automated assistance will allow substantial increases in control capacity. The prediction refers to different types of conflicts such as airspace, planning and separation conflicts /5/. The Experimental ATM Working Position Simulator and conflict prediction/resolution module LOTEC (Long Term Conflict Prediction and Solution System) /12/ implemented into it detect potential conflicts and present them to the controller. By generating and describing the conflict-free solutions if possible, LOTEC make it, thus, easier for the controller to come to a decision.

A conflict prediction based on updated flight plan data (correlation with radar information) is the key element of such a module when analysing conflicts of relevant flights, occured in a period of time to be investigated (time filter). This allows an effective computer-based conflict prediction for only a subset of the generated flight plan list. The process of analysing pairs of flights determines the degree to which both the vertical and the lateral separation standards are violated. Thus, the implemented sequence of filter functions (time, vertical and lateral filter) allows an effective, realtime process of analysis. With regard to a flexible spectrum of research and operation, the user has to define various input parameters, e.g. analysis frequency, separation standards, conflict-free period of time, permitted slot shifting, priority of the measure to be taken for conflict resolution (e.g. variation of speed, flight level, estimated time over, lateral profile). In order to be able to carry out the different kinds of investigations, LOTEC implies different modes of operation:

- Unique conflict prediction and resolution:
    - Sequential processing of the relevant flights; determination of the first potential conflict occuring in the period of time defined before and solution of this conflict;
- A prediction of all conflicts possible and their respective resolution:
    - Automated prediction and resolution of all potential conflicts with respect to the fixed period of time and according to the priorities the controller defined with respect to the different measures;
- Complete conflict prediction without resolution:
    - Automated prediction of all potential conflicts that might occur during the defined period of time.

The automated generation of conflict solutions implies different functions which modify the given flight data. Implemented is the possibility of varying the speed, flight level (Figure 9) and the ETO and of modifying the lateral profile (Figure 10).

Taking into consideration that the controller should be involved in the (semi-)automated processing of conflict prediction and resolution, the generated system outputs (description of the conflict situation and solution) will be presented explicitly in two ways, e.g. as an integrated window of the DROPS system and separately on an additional control monitor (Figure 7).

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##########################################################
LOTEC --- ANALYSIS ---
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Potential conflict at:  16:53:00

AC 01        :HLF132
Interval     :16:52:00 FUL - 16:58:00 LAU
AC 02        :NAD200
Interval     :16:49:00 LAU - 16:53:00 FUL

Description of the conflict situation:
Course          :   AC 01      6
                    AC 02      131
Phase           :   AC 01      -1       1 : Climb
                    AC 02      0       -1 : Descent
Lat. Dist. [NM] :              2.9      0 : Cruise
FL              :   AC 01      332
                    AC 02      330
Rel. CG [ft/m]  :              1733
Trend (30 sec.) : Horizontal: 2.9 NM      Vertical: 666 ft
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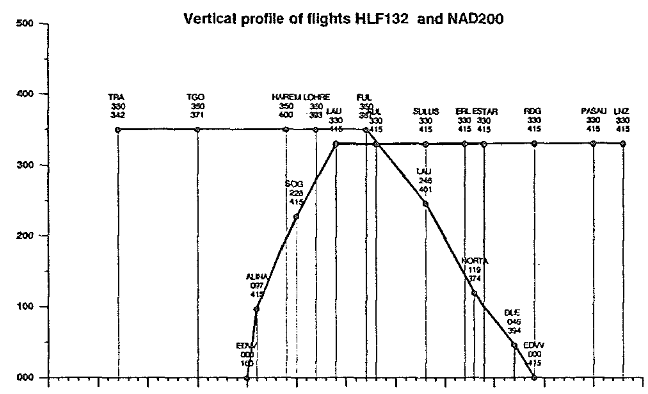

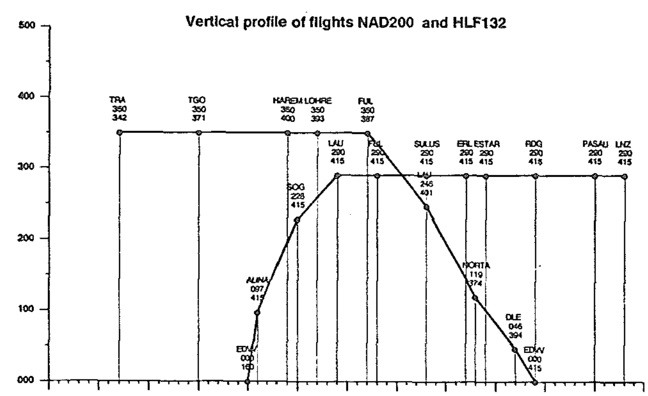

Figure 9: Conflict Analysis and Resolution by Changing the Flight Level (shown is both the vertical profiles with a potential conflict and the conflict solution)

The development of the automated modules assisting the controller with his task of predicting potential conflicts is based on conventional algorithms. This also applies to the conflict resolution as it has been implemented up to now. In future ATM concepts /4, 13, 14/ alternatives to the algorithmic approach of implementing ATC automation aids, such as the Artificial Intelligence (AI) technique, will have to be discussed. These modules could be knowledge-based systems (expert systems), which would be implemented in future ATS systems as an intelligent ´Controller Associate´. With respect to ATM functions, this ´Controller Associate´ can be used in

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LOTEC --- ANALYSIS ---

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Potential conflict at: 10:18:00

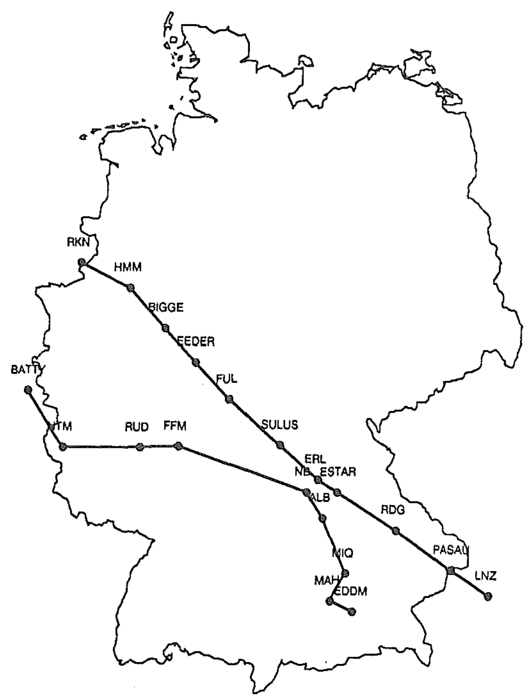
AC 01	:KLM518
Interval	:10:15:58 ESTAR - 10:18:08 ERL
AC 02	:DLH410
Interval	:10:14:30 ALB - 10:18:04 ERL

Description of the conflict situation:

Course	:	AC 01	310	
		AC 02	282	
Phase	:	AC 01	0	1 : Climb
		AC 02	1	-1 : Descent
Lat. Dist. [NM]	:		3.5	0 : Cruise
FL	:	AC 01	390	
		AC 02	389	
Rel. CG [ft/m]	:		985	

Trend (30 sec.) : Horizontal: 0.6 NM Vertical: 392 ft

Lateral profile of flights KLM518 and DLH410



Lateral profile of flights KLM518 and DLH410

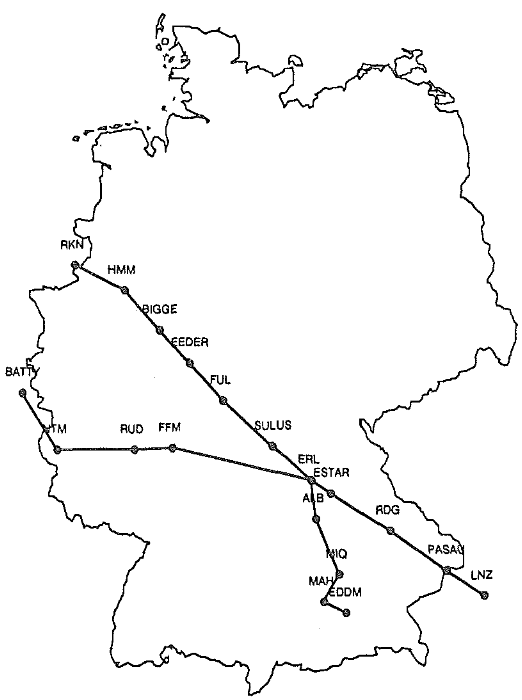


Figure 10: Conflict Analysis and Resolution by Modification of the Lateral Profile

different fields of application such as man-machine interface, traffic planning, traffic coordination and supervising. With regard to the program system LOTEC, it is planned to develop an expert system with a rule-based logic replacing the conventional conflict-solution function. As a first step, the required database has to be developed, which is subdevided into knowledge based on operating instructions and rules /15/ and experiences the controller made himself when solving conflicts. For developing an expert system prototype an AI shell seems to be useful in case of rapid prototyping.

The Experimental Working Position Simulator will be used for the acquisition of knowledge as well as analysis of expert systems used as a ´Controller´s Associate´ in a complex, hybrid ATC system.

5 Application

The experimental working position simulator is both an interactive and realtime simulation system for developing and analysing concepts, procedures and modules concerning different aspects of computer-based ATM, e.g. software engineering, human factors and analysis of traffic.

The simulator supports the following research applications, which are carried out at present or supposed to be conducted in future:

- Analysis and evaluation of air traffic scenarios (enroute traffic; impacts of modifications concerning the structure and organization of the airspace);

- Analysis, development and optimization of ATM-related concepts/procedures/(semi-)automated modules:

  - *Conflict prediction and resolution* (i.a. validation of conventional algorithms by means of simulation);

  - Conflict resolution by expert systems used as ´Controller´s Associate´ (development of a database, inference process, time-based problems, software safety and verification);

- Human factor analysis concerning the future working places of the air traffic controllers:

  - Information required that concern different ATC-related functions;

  - Information processing and representation (man-machine interface, symbols, colour-coding);

  - Interactions of the controller.

The evaluation of the different modules of the working position simulator will be carried out with regard to aspects of human factors. Different simulation scenarios will be defined, which concern both the use of the controller´s aids developed (electronic flight plan data and trajectory representation (DROPS), conflict prediction and resolution (LOTEC)) and various situations involving high/low traffic demand. Different questions will have to be analysed such as the influences the aids have on mental representation of the controller and his strategies to fulfill his tasks, as well as their impacts on the capability, efficiency and reliability of the system. Therefore, the NASA-Task-Load-Index /16/ will be used for analysing the controller´s workload, while a category system (which still has to be developed) will be used for analysing the different activities of the controller, which will be recorded by means of logfiles and video. To have a detailed knowledge about the strategies of the controller is very important when developing an expert system, which will have to be implemented as a ´Controller´s Associate´ in future. It is expected that first results will be obtained towards the end of 1992.

The future Cooperative ATM Concept of the BFS is based on coordination processes taking place between ATC, aircraft and operators. Therefore, different investigations are initiated to analyse the integration of on-board derived data (Flight Management System) transmitted via data link to the computer-based ATC-system (ADS) on the one hand, and on the other, the integration of controller´s instructions that are transmitted via data link to the aircraft avionics. Moreover, it will be necessary to investigate how these additional data influences the cockpit crew. In 1993, a A340 Full Flight Simulator owned by the ZFB (Zentrum für Flugsimulation Berlin GmbH) will be ready for training. The simulator provides normal training operations and additional research capabilities. The A340 is equipped with a Scientific Research Facility which, combined with the Experimental Working Position Simulator, allows the investigations mentioned above.

At present, the capability of the Experimental Working Position Simulator is depending on the hardware used (LAN with PC´s and Transputer). It allows a realtime traffic simulation of 150 aircrafts which are operated simultanously.

6 Summary and Conclusion

Future ATM concepts /2, 3, 5/ are going to reduce the present technical, operational and organizational shortcomings. For this reason, it will be necessary to develop and optimize concepts and procedures including the automated controller aids for computer-aided ATM. These investigations require a flexible and realtime online-simulation system, which is a testbed for development and analyse of both the modules for the (semi-)automated assistance and man-machine interface.

The Experimental Working Position Simulator developed for ATM is a realtime traffic information, planning and coordination system, which is interactive and allows to develop and analyse solutions that concern different aspects of computer-aided ATM. The hardware of the simulator is based on a LAN with networked microcomputers. The different software modules developed are supposed to simulate different air traffic scenarios, present flight plan data and flight trajectory electronically and modify them. Moreover, they are expected to predict and solve potential conflicts. Various functions are implemented to interact with the data processing system that regards the man-machine interface.

The Experimental Working Position Simulator is used to analyse and evaluate air traffic scenarios concerning the influence of modified airspace structure and organization. Furthermore, the software modules developed and implemented into the simulation system (electronic flight plan and trajectory display, conflict prediction and resolution) will be analysed, evaluated and optimized with regard to aspects of human factors. This requires that realtime simulation of various scenarios are carried out in cooperation with controllers. Furthermore, the workload will have to be determined under conditions when different automated aids are used.

In the near future, another application will be started to analyse both, the integration of onboard derived data (FMS) into the ATC system and the integration of ground derived data (ATC instructions) into the aircraft avionic systems. These investigations require that the Working Position Simulator is linked to a Flight Simulator. This is expected to be done in 1993.

The current capability of the Experimental Working Position Simulator allows a realtime simulation of 150 aircrafts. This is sufficient for most investigations carried out in this connection. If realtime is not of interest, the simulation system allows a traffic simulation of 1000 aircrafts. To increase the system capability with regard to a realtime processing, the hardware environment has to be changed.

7 Abbreviations

ADS	Automatic Dependent Surveillance
AIP	Aeronautical Information Publication
AMSS	Aeronautical Mobile Satellite Services
ARRCOS	Arrival Coordination System
ASM	Air Space Management
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Services
ATSAM	Air Traffic Simulation Analysis Model
ATN	Aeronautical Telecommunication Network
BFS	Bundesanstalt für Flugsicherung
CATMAC	Cooperative ATM Concept
CIDIN	Common Integrated Data Interchange
CMTP	Common Medium Term Plan
CNS	Communication, Navigation, Surveillance
DEPCOS	Departure Coordination System
DROPS	Dialogue-oriented Route Online Planning System
EANPG	European Air Navigation Planning Group
EATCHIP	European ATC Harmonization and Integration Programme
ECAC	European Civil Aviation Conference
ETO	Estimated Time Over
FANS	Special Committee on Future Air Navigation Systems
FEATS	Future European ATS System Concept
FMS	Flight Management System
GNSS	Global Navigation Satellite Systems
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
LAN	Local Area Network
LOTEC	Long Term Conflict Prediction and Solution System
MATIS	Microcomputer-based Air Traffic Information System
PMS	Performance Management System
RNAV	Area Navigation
RNPC	Required Navigation Performance Capability
SSR	Secondary Surveillance Radar
VFR	Visual Flight Rules
VHF	Very High Frequency

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