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ABSTRACT Air Traffic Management in Europe has to be able now and in the future to provide sufficient capacity to be in balance with the demand. Staggering delays the last years made clear that the shortfall of capacity became unacceptable. The basic requirements of Airline Operators to ATM emphasise the need for sufficient capacity, punctuality and quality of service to perform their flights in a cost-effective and efficient way. Other requirements stem from the increased load of air traffic on the environment and the threat of safety risks. The development of advanced ATM and advanced CNS, as enablers, are the basic means to address the problems and to solve the deficiencies. Management and control of air traffic from gate to gate is subject of long-term improvement programmes. However, all concepts addressing potential enhancements of ATM are affecting an extremely complex and tightly tuned system of operations. This paper presents an overview of the major concepts of ATM, guiding the enhancement programmes in Europe. As discussed, most concepts have critical side effects and not very much progress has been made with operational implementations of new functionality.				



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ATM/CNS: The response to the current and future needs

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Summary

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Introduction

Serious concerns about the performance of ATM in Europe arose when the steady growth of air traffic started to cause a spectacular increase of delays at the end of the eighties. In particular the major “hub” airports of Europe got overloaded and all air traffic related directly or indirectly to aircraft movements to and from these airports were suffering delays due to structural traffic congestion problems. Although several causes were identified as being responsible for the problems, and not in the least the runway capacity problems of the major airports, the most important reason for malfunctioning was assigned to shortfall of capacity of Air Traffic Control (ATC) in Europe. It was recognised that Air Traffic Management (ATM) as the collection of all those activities concerning the organisation and management of the successful provision of Air Traffic Services, had to be improved urgently, and several initiatives were undertaken on a national and international level to enhance ATM in Europe. By far the most important attempt to solve the problems was the EATCHIP initiative (European ATC Harmonisation and Integration Programme), conducted by Eurocontrol on behalf of the ECAC (European Civil Aviation Conference), with the objective to achieve an increase of ATC capacity in the ECAC area, sufficient to reduce delays of commercial air traffic to an acceptable level. The success of EATCHIP was remarkable and up to the end of the nineties ATM improvements with a limited scope, based on the concept and architecture of the available operational ATC systems, were sufficient to cope with the demand. However, reaching the year 2000, the delays were staggering again and a notable feeling of discomfort became apparent of the Airline Operators, suffering directly from the inconsistency and inadequacy of ATM in Europe. Amongst others they complained about an increasing discrepancy between the high-tech avionics on-board and the very slowly modernising world of ATM on the ground. As direct stakeholders of ATM they required action to solve the problems, and, in response, Eurocontrol published the ATM2000+ Strategy Document [Ref. 1]. This document can be considered at present as the leading document to describe the strategy to be followed to improve ATM in Europe. An appraisal of the current and future needs of ATM in Europe will be, and has to be considered therefore in view of this strategic plan.

The functioning of ATM in Europe at present is assessed firstly by considering the achievements of operational improvement programmes, and secondly by discussing some of the achievements of the various completed and ongoing R&D programmes in Europe. Consolidation is expected of concrete results as mature, validated components for operational implementation, but apparently realisation occurs slowly. Here, the real discussion starts about the response to the current and future needs of ATM. The targets to be set are reasonably clear; there is a steadily growing demand of air transport. However, what is less clear is the way ATM has to respond to cope with the demand when ATM enhancements have to become concrete.



Some innovative concepts and the expected success of ongoing and future R&D will be discussed and analysed, and the achievements will be discussed in the perspective of R&D programmes of the last 10 years, as well as the results for which the ATM world is waiting yet. Why is it extremely difficult to come to mature operational implementations, why is the success-rate low, and why are the costs so high? Are there valid reasons for resistance against advanced technologies and innovative concepts? And how to realise the main challenge, formulated by the ATM2000+ Strategy document, to come to a successful advanced ATM system for a Gate-to-Gate concept, offering an integrated approach to provide Air Traffic Services (ATS) with sufficient interoperability to the users of ATM, the Airline Operators and the Airports? These questions form the background of what is discussed in this paper.

Overview of what is achieved and how ATM functions in Europe at present

The EATCHIP programme, conducted by Eurocontrol, has set the trend for development and implementation of ATM in Europe during the last decade [Ref. 2 and 3]. This operational implementation programme served a double objective:

- Development and implementation of new concepts and new functionality of which one of the most striking and most successful elements is the CFMU (Central Flow Management Unit), come into operation in 1996 and dealing with planning of air traffic flows through the whole ECAC area.
- Implementation and harmonisation of functionality in the different ATC centres. This part of the programme was performed by execution of CIPs (Convergence and Implementation Programmes) for each of the individual ECAC member states, and an important objective was to achieve homogeneous radar separation minima over large parts of Europe [Ref. 3].

EATCHIP was completed in 1998, when it was superseded by EATMP. Although not all centres in all ECAC states were fully equipped yet in agreement with the CIPs and although full compliance with the anticipated Operational Concept for EATCHIP Phase III was not achieved, most parts of Europe were equipped at an equivalent, harmonised and improved level. What was achieved at that time was measured first of all by the implementation level of the enabling technologies: CNS (Communication, Navigation and Surveillance) and the associated data processing capabilities.

The results of EATCHIP are summarised very briefly. The target settings for surveillance were to provide tracked flight data, based on double radar coverage, for all controlled air traffic on the controllers' PVD (Plan View Display). For navigation the introduction of B-RNAV (Basic-Area Navigation) was realised providing the technology to enable more direct routings and for communication the introduction of datalink networks between ATS centres, providing advanced means of communication in addition to voice communication. Ground-ground data networks

were built: a network to exchange flightplan information between most of the centres in the core area of Europe, based on the OLDI (On-Line Data Interchange) protocol, and a data network to exchange radar plot information, RADNET (Radar Network), for the 4-states/Eurocontrol Integration Project (Germany, Belgium, Luxembourg and the Netherlands).

The EATCHIP Phase III functionality for the ATC automation can still be considered as almost the state-of-the-art of the present-day ATC system. (For a high-level functional architecture scheme of EATCHIP III, see Figure 1, derived from reference 4.) The implemented functionality consists mainly of multi-radar tracking software to process radar data, and flight data processing software to process flightplan updates, communicated via OLDI, as well as correlation software to identify tracks with flightplans.

Some more advanced automation functions are available from specific development projects for individual centres and developed under responsibility of the local ATS provider, e.g.:

- *Safety nets*: STCA (Short-Term Conflict Alert), giving alerts for potential hazards, such as e.g. the risk to lose the required separation on short term between a pair of flights,
- *Monitoring aids*: e.g. to detect deviations from planned flight trajectories,

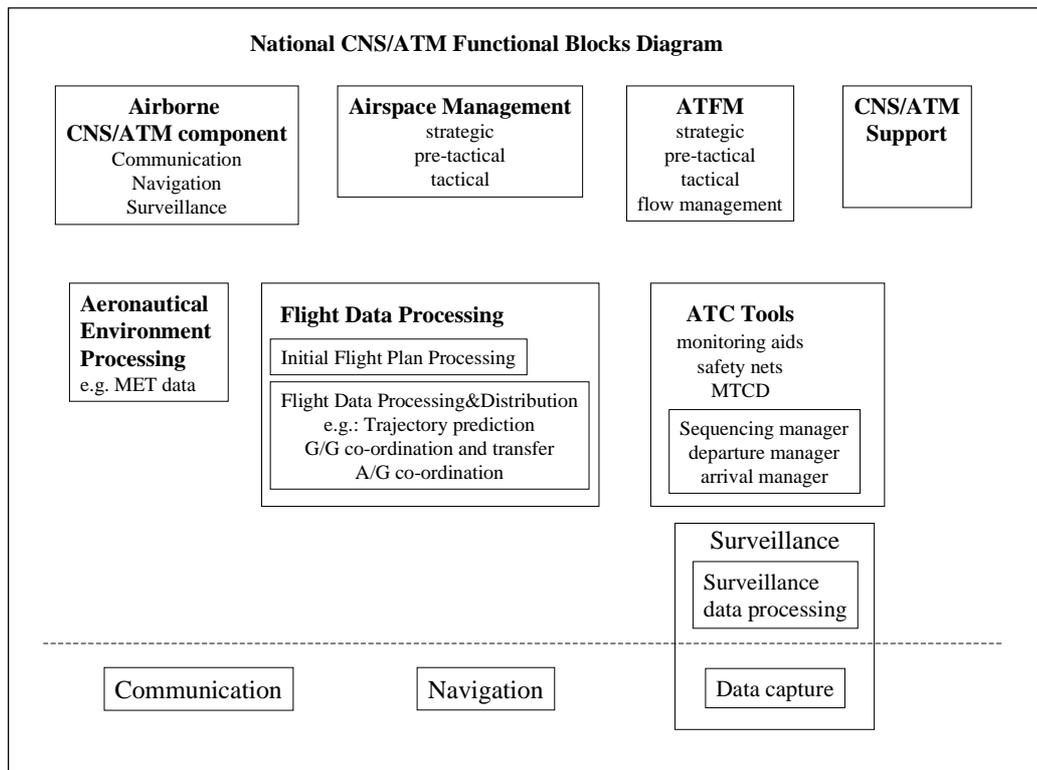


Figure 1 - High level functional architecture of national CNS/ATM of EATCHIP III, a simplified scheme



- *Medium Term Conflict Detection*: e.g. to detect loss of separation between a pair of flights, by processing planned flight trajectories and analysing proximity conditions, and
- *Sequencing Managers*: AMAN (Arrival Management) and DMAN (Departure Management). Arrival Managers are operational at present at a few centres only. These tools usually calculate an estimated approach time to enter the TMA taking into account the most appropriate sequence of landings. The objective of this tool is to support the controllers to prepare a proper sequence of landing flights at an early stage, e.g. some 10 to 15 minutes before the actual merging of arriving traffic flows coming from different directions.

In essence, the automation system offers the controller flightplan information and surveillance information. At a modest level there is some assistance with alerting functions to trigger the controller for an activity. In spite of automated support the executive controllers still perform all ATC tasks, in a purely tactical manner, i.e. they:

- Plan the flight through their sector, and determine solutions for problems and conflicts,
- Communicate with the pilot, and receive information concerning actual flight conditions,
- Provide guidance and submit clearance instructions to the pilot,
- Monitor the surveillance information and detect potential problems, and
- Communicate with other actors, such as controllers of adjacent sectors.

If the achievements of EATCHIP III have resulted in a significant increase in capacity (40% to 60%) [Ref. 3], the reason was not only that the harmonisation of implementations has led to a continuous and equally available level of service provision, but, at least as important, the organising, planning and structuring of air traffic flows was achieved successfully by the complementary development of new functionality for ATM, such as:

- *Air Space Management*: An instrument to manage, to organise and to improve the availability of airspace. The concept of Flexible Use of Airspace was introduced allowing more dynamic availability of airspace and flexible use of airspace by civil and military users. Also, the regular optimisation of the available route network provided opportunities to realise an increase of airspace capacity.
- *Air Traffic Flow Management*: By creation of a Central Flow Management Unit (CFMU) the pre-departure management of air traffic flows was ensured in an integrated way over the whole ECAC area. Flow Management acts from half a year before departure up to the actual departure. By this process sector overloads are avoided and traffic densities are smoothed by applying sector regulations and by assigning departure slots to each flight.

What was already recognised in EATCHIP as potential new functionality, but what is at present still hardly available in the operational environment, is the use of an air-ground datalink.



The air-ground communication is still almost purely voice based. What was also completely missing in EATCHIP and what has been added in the subsequent programme, EATMP, is the involvement of other actors in ATM. This concerns the roles of the aircraft and the pilot, the roles of the Airline Operators with their Airline Operations Control centres (AOCs) and the Airports. If anything fundamentally changed the view on ATM, and the scope of development of new ATM functionality, it was the re-estimation of the role of these actors in the ATM process. This can also be expressed by stating that each of these actors had developed their own automation systems for planning, guidance and control of those activities that were their own concern. Only lately, it was discovered that essential misfits occurred by the existence of planning, guidance and control processes which were focusing on the same objects, i.e. the execution of flights, but which were handled independently of each other. The first broad initiative to address these topics can be found in the ATM2000+ Strategy document. Its objective is the realisation of a uniform European ATM for the timeframe 2000 to 2015 [Ref. 1]. This report is the main driver for concepts, determining “the current and future needs of ATM”.

Overview of the current and future needs of ATM according to the EATMP

The EATMP (European ATM Programme) has been developed by organising broad discussions with all actors involved in ATM, and by producing, before the ATM2000+ Strategy document, an Operational Concept Document [Ref. 5]. This paper will only highlight those elements and concepts that caused the major changes in thinking about how to perform ATM in Europe in the future in a more satisfactory way. The main drivers will be recalled that gave the lead to come to a strategy, that meets the needs of the stakeholders with their direct interest in the performance of ATM, i.e. the Airline Operators and the Airports.

The first driver for the EATMP was to contest the rapidly accumulating delays and to solve the traffic congestion problems. The focus was initially to achieve an increase of capacity of the major airports, their runways and lower airspace, but at present, a steady number of regulated en-route sectors are causing capacity problems also and are acting more and more as the bottlenecks of air transportation in Europe.

However, capacity is not the only driver. The complexity of properly organising the flows of traffic is causing concerns to the Operators on account of inefficiency, fuel costs and loss of time. Flights are often forced to deviate significantly from their most economical direct routings or are forced to fly at less than optimal altitudes. Other concerns are the rising costs of the process of ATM itself, the shortage of qualified controllers and the threat of loss of safety due to the increasing traffic density. With respect to safety the firm objective is to maintain or improve the present level of safety, even with an increasing amount of air traffic.



The traditional role of ATC was expressed always quite simply and straightforward by the words: “safe, orderly and expeditious”. One of the main drivers for a change in thinking was the move from just accepting the executive tasks to a broader and more pro-active attitude, reacting on the explicitly expressed priorities of the Operators for cost-efficiency, punctuality and safety. As such, a set of target settings and top-level objectives were derived in the Strategy 2000+ document under the headings:

- Safety,
- Economics,
- Capacity,
- Environment,
- National security and defence requirements,
- Uniformity,
- Quality, and
- Human involvement and commitment.

Some objectives are forthcoming from the European dimension of the EATMP. Important is the significant increase of use of airspace that is achievable when control on civil and military air traffic can be integrated where possible. Flexibility in use of airspace was achieved with introduction of the Flexible Use of Airspace (FUA) concept in 1996 and the criticality of this concept becomes clear when one realises that at present not necessarily the runway and the airport capacity are the constraining factors, but that rather some en-route sectors are causing most capacity bottle-necks in Europe. That is not due to a lack of airspace but to a lack of organisation and management of airspace.

The objective to optimise capacity is not really new, but has become a more principle objective since the capacity shortage has become a structural element of ATM. The most structural elements to achieve an increase of capacity are the infrastructure of the airport, the volumes of available airspace, the efficiency in use of available airspace, and options to improve in general the accuracy of planning, guidance and control. Hopefully, an increase of capacity can also be the result of a potential decrease of the required separation.

Safety has always been the main driver, but its meaning, and the attention it received, have changed. There is definitely a much larger interest than in the past in the safety effects on the affected population, the so-called external risks, in contrast to the internal risks, the risks of the passengers and the crew. As a consequence the research into safety effects has made quite a large progress. It is not anymore just one of the ATC executive tasks to maintain safety, but it is one of the requirements for innovative ATM concepts, that they are analysed deeply on their consequences for safety.



Finally, the attention to the Environment is relatively new, and it demonstrates the recognised importance to pay attention to the avoidable and non-avoidable load of air transportation on the population in the environment and their quality of life. It is realised, and it is evident, that noise abatement and containment of emissions play a major role in the acceptance of the tolerated volumes of air traffic movements. Specifically around the airport, Safety and Environment belong to the main objectives for all ATM operations in a constant and tense relationship with Capacity and Cost-efficiency.

Derived from these major objectives, some of the most important concepts in view of the ATM2000+ Strategy will be discussed below. What are these concepts aiming to achieve? And how realistic are their chances? These are some of the questions raised.

The following selection of ATM concepts will be dealt with:

- Airspace Organisation and Management
- Flow and Capacity Management
- Layered Planning
- Free Flight
- Collaborative Decision Making (CDM)
- The role of the human in ATM

Airspace Organisation and Management

The extension of “Airspace Management” with “Organisation” is probably expressing very well what was missing. The traditional structure of airspace, based on national boundaries, is absolutely inefficient and inadequate by now. Another recognised factor that contributes to an inefficient airspace structure is the increasing fragmentation due to the habitude to solve controller capacity problems by splitting sectors, and to gain controller capacity at the price of airspace capacity.

There is a recognised and urgent need for a full reorganisation of European airspace, and Eurocontrol and the EC are pushing this with their policies: “One Sky for Europe” and “A single European Sky”. The expected benefits are straightforward a significant increase of capacity. Elements of a re-organisation of airspace are:

- *More access of civil air traffic to military airspace:* Availability of military airspace for civil use solves a capacity problem when airspace availability is achieved in such a regular and structural way that Operators can plan part of their traffic over these temporary routes. The so-called Conditional Routes (CDRs) are appropriate to meet this objective. Of course, a further integration of control on civil and military traffic could improve the capacity even more, and could be achievable, in principle, as long as military operational exercises are excluded. However, the potential to enable such an integration of traffic might depend on traffic complexity and might require therefore also advanced monitoring and conflict



detection options, as supportive automation tools required to maintain sufficient situation awareness.

- *RVSM*: Reduced Vertical Separation Minima (RVSM) will provide a number of extra available flightlevels in Upper Airspace. The direct benefits are to provide additional capacity. Important indirect benefits could possibly be achieved in supporting control of arriving traffic around the airports. An advanced arrival management process is asking for early sequencing, initiated at a greater distance and at a higher altitude than at present. Most of the arrival management process, the sequencing, metering and merging of arrival flows, is at present still established after passing the Metering Fix, close to the airport, or in small-sized and low-altitude ACC sectors.

The introduction of RVSM is delayed. Some reasons are the associated required re-organisation of airspace and services, the problems with transition areas, and the human resource problems, due to the required number of extra controllers. Also, the certification of the necessary aircraft equipment is delayed.

- *Re-sectorisation of airspace*: The problem of Arrival Management around the major airports has to be solved not only by an extension of the number of available flightlevels, but also, proportionally, by a horizontal extension. An optimal definition of these sectors can become beneficial to the efficient use of available runway capacity at airports, such as the Brussels International Airport, Schiphol and Düsseldorf. However, at least, in the core area of Europe, the proper definition of suitable arrival sectors will create a very complicated puzzle of entangled sectors, and to realise this, it is essential to focus on the determining elements of adequate sector definitions, and to overcome the severe limitations imposed by national boundaries and segregated use of airspace.

Flow and Capacity Management

The notion of “Flow Management” was extended in the ATM2000+ Strategy document with the term “Capacity Management” to express the urgent need not only to enable ATM to achieve proper management of the available capacity, but also to control the demand. Notwithstanding the noticeable success of the CFMU in preventing serious overloads, the initial CFMU flow planning mechanisms showed some shortcomings. Flow regulation yields to the definition of slot assignments with a tolerance of 15 minutes. This tolerance is large for in-flight planning. Also the inflexibility for re-planning, and the lack of transparency of the planning process are major concerns of the Operators. The CFMU recently started projects to improve transparency and to improve the feed-back on capacity planning constraints towards the Operators, and this has resulted already in enhanced interactive planning and more re-planning capabilities.

However, more remains to be done.

The Airline Operators have asked for options to improve the potential to manage delayed flights and to enable them to swap and shift slots, and thereby to avoid losing slots [Ref. 6]. At present



Operators must ask for a new slot, causing often a long extra delay. The current practice to overcome the problems, if possible, is to ask ATC for slot extensions, but this practice slowly corrupts the integrity of the flow planning with a risk of congestion whereas it was attempted to avoid this, and at the same time a risk to miss optimal use of the available capacity, because the aircraft are just not there, where they were planned and expected. The inability to cope with the dynamics of the process of the pre-departure flight preparation and execution causes an ineffective use of the available capacity, but conversely, when flights are not able to cope with a tight and accurate planning, the effectiveness of flow management deteriorates.

Anyhow, while a proper realisation of the planning should aim not to miss its targets, there is a need not only to press the actors to adhere to their planning, but also to allow sufficient flexibility for re-planning. This implies at least requirements to improve the options to timely release slots after cancellations and delays, and to achieve agreements with the Operators on mechanisms for a more effective optimisation of slot re-assignments.

Layered Planning

As discussed, there was the problem of a pre-departure flow planning, performed about two hours before take-off and ending with an uncertainty of about 15 minutes for individual flight planning. On the other side, there is the in-flight planning which starts normally about a 10 minutes before FIR or sector entry and which has a planning range normally not extending the sector size. Layered planning was proposed therefore “to bridge the gap”, and to refine the planning process in such a way that planning becomes a continuously refined convergent process. The objective is to perform planning not in more detail than will be allowed by the options to control the occurrence of disturbing events. Moreover, planning should not be overly constraining on the freedom and flexibility to optimise the execution of a flight. The result should contribute to a decrease in the number and impact of interventions on flight progress, and to a decrease of workload and an increase of efficiency and capacity.

Another “natural” reason to pursue the extension of the planning range is the progress in development of advanced avionics, and specifically the FMS (Flight Management Systems), allowing planning to extend very significantly beyond the size of a sector. The ATS providers are still performing ATC basically in a purely tactical manner, and their planning is based on just their own centre-based and sector-based scope of operations. If ground-based planning has to be able in the future to cope with airborne planning capabilities and, the other way around, be capable to serve airborne planning processes with ground-based planning constraints, then the planning range has to be extended. However, the benefits of coupling planning processes become visible only if there is a fair chance that plans can be realised undisturbed and that the number of corrections stays limited.

On the one hand, “bridging the gap” asks for a refinement of pre-departure flow planning and ATC departure planning. Refined flow planning may be achieved by integration and fine-tuning



of planning, e.g. by integration of in-flight planning of long-haul flights and pre-departure planning of short-haul flights. Another pre-requisite is the timely feed-back of planning changes from Airline Operator, Airport and ATC towards the flow management planning.

Pre-departure planning would be suitable to support early in-flight planning if it is possible to reach accuracy in the order of about one minute. Better is fairly impossible due to the inherent uncertainty of actual departures, and it can never be the priority during take-off to meet a planning constraint. However, if the accuracy aimed at can be realised, benefits can be achieved by improved in-flight flow control.

On the other hand, extended in-flight planning asks for a peculiar planning process generally referred to as: "Multi-Sector Planning". There are severe constraints to make medium-term

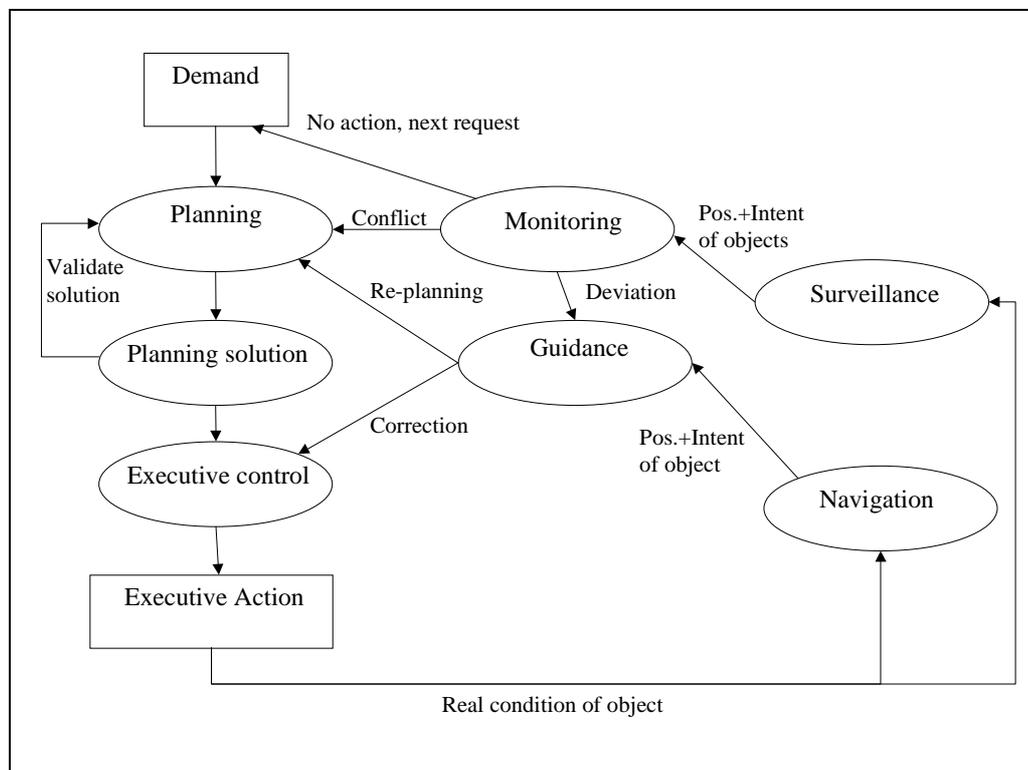


Figure 2 - A generic model of a guidance and control loop in an ATM process

planning (up to about 20 minutes ahead) profitable for the planners and for those who must realise the planning. Any extension of planning implies a loss of flexibility if the planning is to be taken as a firm commitment. Fortunately, for air transportation it is in essence profitable to adhere to a tightly and accurately planned process, and it can be directly beneficial to the punctuality. The improved guidance and control capabilities of the aircraft are the ultimate justification to establish this extended planning.

To discuss the best potentials of pilot and aircraft on one side, and the controller and his automated support systems on the other side, a generic scheme of the process of ATC is



considered (See Figure 2). With present ATC, the controller performs almost the full process; the role of pilot and aircraft is restricted to proper response by performing executive actions and by navigation. The controller is performing himself the complete main control loop of monitoring, guidance and control. This is essentially a feed-back control loop with rather poor performance characteristics, and it is amazing that it is so difficult to beat the perfection of the present operations in terms of safety and efficiency. Effectively, the controller will not give much more than a few instructions within a 10 minutes sector transit period, and awareness of deviations is based on radar surveillance data with limited speed information only. This system works thanks to the extremely professional and circumstantial experience of the pilots and controllers.

However, for extended planning to make sense, the functioning of this feed-back control process has to be improved in terms of frequency of ATC control actions and accuracy of guidance information provision, and ultimately also in control of the aircraft. The aircraft is capable of providing the underlying data, and the guidance and control, using its FMS and flight

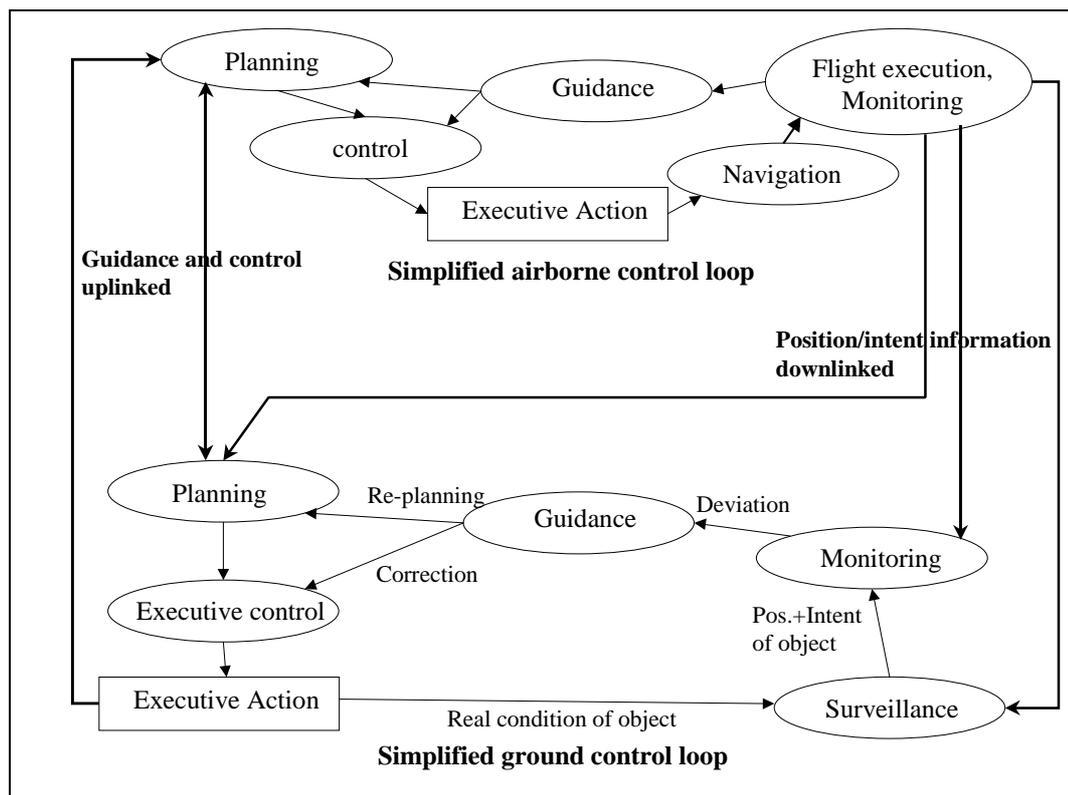


Figure 3 - Exchange of information between airborne and ground guidance and control processes.

control systems; however, the ground ATC system has the overview and the competence for decision making. It is hard to affect these roles as long as traffic conditions are complex and



strategic planning problems have to be solved. A high level scheme of distributed control functions is shown in Figure 3. The realisation of different types of more or less intensive information exchange between aircraft and ground is still in a preliminary stage of development.

In all cases, it seems by far not feasible to build automation systems able to react adequately under all thinkable and unthinkable exceptional conditions. Therefore, the requirement that pilot and controller are able to deal with exception handling implies that they are in control of almost all aspects of decision making. Possibly this is the most severe restriction on the feasibility of building advanced functions for ATM to improve the feedback control loop.

Free Flight

The conceptual idea of Free Flight was invented in the USA, and this concept formed the basis to develop the NAS (National Airspace System) Architecture Plan of the FAA (Federal Aviation Administration). The NAS Architecture Document [Ref. 7] refers to an RTCA definition of Free Flight as: "... a safe and efficient operating capability under instrument flight rules in which the operators have the freedom to select their path and speed in real time. Air traffic restrictions are imposed only to ensure separation, to preclude exceeding airport capability, to prevent unauthorized flights through special use airspace, and to ensure safety of flight. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restrictions represents a move towards Free Flight". This definition allows a wide interpretation about what can be covered by Free Flight.

The same document states as one of the important objectives of Free Flight: "A key benefit to users will be their ability to select and use efficient flight profiles ...". This expresses quite well what is possibly one of the main drivers to push Free Flight, i.e. the strongly felt need of Airline Operators to get more initiative and more control on planning and execution of their flights.

The most far-reaching implementation of Free Flight should offer the pilot not only the freedom to plan the flight's profile, but also to perform many tasks carried out normally by ground ATC. Advanced CNS equipment and advanced avionics, like ASAS (Airborne Separation Assurance System), should offer the means to survey traffic and execute a flight separated from other traffic. Less far reaching implementations of Free Flight retain the principle of the responsibility of ATC to plan and control the traffic, and focus rather on free routing, possibly extended with a limited delegation of the responsibility to maintain separation. It is this last option that is adopted in the EATMP to improve the service provision of ATC in the future in the upper levels of en-route airspace.

Although full delegation of responsibility for separation may seem over-ambitious, implementation of this concept can be considered in areas with a very low density of air traffic,



and with missing or unreliable ATC services. The requirements on additional aircraft avionics equipment are high, and it may imply a considerable extension of the tasks of the pilot, but potential benefits in terms of capacity, efficiency and safety, are evident.

Free routing is less demanding for the required level of on-board equipment. Also, the changes in the mode of operations are less radical, as well as the impact on the roles of involved parties and of new systems to be developed. Nevertheless, the implications for ATC are far reaching also. Although free routing will not comprise unplanned, unpredictable and arbitrary routing, this will place an extra load on the controllers. E.g. if the structuring and organisation of traffic flows are missing, there is no ensured separation of traffic flows from the very start of planning, as is usual the case. Further, the number of crossing points will multiply and these points will not be at the selected favourable places.

Another issue is that efficient routing does not necessarily provide the expected economical benefits unless there is a seamless co-ordination on efficient arrival planning. Therefore, also flights in Free Flight airspace have to be subject of an integrated gate to gate planning process.

To solve the air traffic control problems, it will be required at least to support the controller with additional tools to enhance his situation awareness, e.g. displaying the routing of each flight. Also, automated support tools will be required to exchange planning proposals between air and ground and to alleviate ATC tasks for planning, monitoring and control, e.g. by applying EATCHIP III functions, such as MONA (Monitoring Aid) and MTCD (Medium-Term Conflict Detection). Even then, tactical control could become more complicated than before and workload may increase rather than decrease.

An add-on function of Free Flight that might be considered applicable, possibly in combination with free routing, is “station keeping”. The pilot is tasked to maintain separation with preceding aircraft. Evidently, this will cause a certain shift of workload from ATC to the pilot, and this will require also a sufficient level of advanced on-board avionics.

The Free Route Airspace Concept is under development for eight Northern European countries and Eurocontrol [Ref. 3]. There are also options to apply free routing in the Mediterranean. The potential benefits are in the first place economy, efficiency of flight and efficient use of available airspace capacity. Moreover, improved flight efficiency will lead to reduced emissions, and therefore also to environmental benefits.

Collaborative Decision Making (CDM)

Collaborative Decision Making (CDM) originated, just as Free Flight, in the USA, and was adopted in the European programmes. As for Free Flight, the conceptual ideas for CDM come in the first place from the strong need, felt by the ATM users, to be more involved in the ATM process, to be better informed and to be enabled to actively participate, where appropriate.



The extensiveness of management and planning activities of CFMU, ATC, Airline Operators and Airports is huge, the activities concern the same flights, and nevertheless the coupling of planning processes is still rather poor. Except for established procedures to accomplish assignments of departure slots from the CFMU, most of the communication is still performed by telephone. Because all parties involved use computer systems for planning, the exchange of information and the coupling of processes seem natural to strive for.

CDM can be applicable in any part of ATM and in any phase of flight. An overview of potential CDM applications in Europe was produced by Eurocontrol in 1998 [Ref. 6]. 22 Different applications were identified, ranging from merely a passive exchange of information to the introduction of active participation in decision making. CDM is particularly beneficial where information of other actors is required for own decision making, or where planning and decision making of different actors may be conflicting or inconsistent. The Airline Operators plan their flights literally from gate to gate, but take into account interests extending far beyond individual flight planning. E.g., missed connections, costs of delayed transfers, and the so-called reactionary delays by delayed turn-around movements, are taken into account (a planning of flights from en-route via the airport to en-route again). At the other side, local ATC planning extends to the size of a FIR at most, and will not consider other interest than to provide safe and efficient ATC services. Therefore, a good reason to apply CDM is when the difference in scope of interest and the difference in availability of information may prevent an optimal flight performance.

The most attractive applications were identified around the preparation of the flight departure phases and the arrival phases. The Airline Operator has a high interest in control on planning, flexibility to react on delays, the capability to anticipate on capacity shortfall and also the flexibility to opt for departure prioritisation when necessary. Also, several actors are active during the departure phase, and an appropriate realisation of the departure planning requires a seamless co-ordination and collaboration of all actors involved.

In the arrival phase the interest is double. On one side timely information provision on a planned arrival sequence may influence, and may be beneficial to gate management, planning of airport surface activities, and planning of return flights. On the other side, the Airline Operators have their own planning, and their preference to realise an arrival sequence of their own flights, but, at present, the arrival sequence is determined by ATC without any knowledge of airlines' preferences.

Receiving detailed data on flight planning from the Airline Operators would be beneficial to the accuracy and realism of initial ATC planning.



The role of the human in ATM

The present roles of controllers and pilots in ATM are still determined by the traditional modes of operation. Modernisation of ATM has brought several enhancements of the underlying technology, but the basic means of control still rely on the picture of the air traffic situation in the executive controllers' mind and the capabilities of the pilot to control the aircraft and to react on ATC instructions. Major changes for ATC were the use of rasterscan display technology, the use of an increased amount of computing power and an increase of ground-ground datalink communication, but the ATC process itself is still relying on voice communication between controller and pilot, on traditional flightplan information and on radar surveillance information.

However, the implementation of the ATM concepts discussed above will require essential changes in the role of pilot and controller. The new ATM concepts are aiming to increase the planning horizon and to achieve more capacity. The result is an increase of air traffic and possibly a reduction of separations. The pilot has to cope with new tasks of planning, datalink communication, co-ordination on planning with his own companies' AOC, and with ATC. He is able to handle these tasks only if he is able to rely on advanced supporting tools, like his FMS and advanced flight control systems to assist him in his work.

The executive controller has to face an air traffic situation determined largely by activities beyond his scope, while also the rationale of decision making can be outside his scope. Possibly, the best enhancements for tactical control are to develop supporting tools to relieve the monitoring tasks of the controller, such as support by MONA (Monitoring Aid), but in other respects it seems difficult to improve a tactical decision making process, based on a mental picture and direct voice communication with the pilot. A proposal to improve situation awareness is to enhance the radar display with an option to filter relevant information. One flight is selected and pushed to the foreground of the display together with related traffic. This concept originates from research performed by PHARE [Ref. 8] and is now part of the development of CORA (Conflict Resolution Assistant).

Any solution that relies on planning aids and datalink transactions between air and ground, seems to be too labour intensive and too slow to solve the problems in the tactical control phase, although these applications can be applicable in Oceanic airspace or Upper Airspace en-route, where decision making is less time critical. Also, any reliance on automatic decision making has to be rejected as long as the tools are not capable enough to be fully competitive with the quality of controllers' decision making and unable to cope with all possible air traffic conditions. Ultimately, ATC is still fully dependent on the executive controller to deal with exception handling, and therefore the requirement of the controller stays firm to preserve his mental picture and to be able to implement decisions in the most direct way by voice communication with the pilot.



The restrictions on enhancements of the capabilities of the tactical controller are a serious barrier to achieve the aimed increase of capacity, because it threatens the aims to increase the sector size or the amount of traffic to be handled by each individual executive controller.

R&D experience and conditions for favourable innovative concepts

The EATMP is aiming for practical achievements with far reaching objectives. The reality is a little bit tough unfortunately and the experience with R&D to foster the development of an advanced ATM in Europe has learnt us the last 10 years, that it is unrealistic to expect that all objectives will be met within the estimated timeframes. This section summarises some conclusions of recent experience to distinguish the most realistic perspectives, focusing on the development and prototyping of advanced functionality and technology, applicable to ATC.

A lot of research has been carried out at the national and international level to prototype and develop new functionality for ATC systems. Amongst the largest programmes belong the PHARE programme [Ref. 8, 9 and 10] and the many projects of the framework programmes of the EC.

An overview of the most relevant main topics yields to:

- Ground-based supporting tools, such as MTCDD, Arrival Manager, Departure Manager and a 4D Trajectory Predictor,
- Ground-based HMI, introducing windowing techniques to address the requirements for interactive access to the supporting tools,
- The development of datalink networks and applications, in particular air-ground applications, to support information exchange, co-ordination on planning, and the issuing of controller instructions,
- Prototyping of a 4D FMS, to support the coupling of air and ground ATM activities at an airborne level.

The overall conclusion is that only very few concepts were mature enough for early operational implementation. In general, it was underestimated how complete and consistent a tool design had to be in order not to generate at least adverse effects on the workload. In this respect the less time-critical planning tools turned out to be a lot more promising than tools supporting tactical operations. However, tools to support planning are beneficial only if they are causing a decrease of tactical interventions and the tactical effort to come to decision making. In most real-time simulation experiments it appears to be difficult to assess quantitatively such a decrease of workload. The comments of controllers were often positive, but always with streams of comments on required improvements.



It is the author's impression that in order to come to better acceptance, some strong requirements should be imposed on:

- *A good business plan with benefits to involved actors:* E.g. the CDM applications require the coupling of complex automation systems. Realism determines that applications have a good chance only if reciprocal benefits can be identified.
- *Avoidance of over-complexity and existence of a transition plan:* Any development requiring modifications of the avionics turns out to be a major effort with risks of delayed introductions.
- *Reliable, validated and certified software:* Daily experience with crashing software tends to influence the norm of acceptance and the risk of unreliable software is definitely one of the reasons to be reluctant to become dependent on the performance of automation systems. Functional tests are in general unreliable in this respect, and implementation within a distributed processing environment is always risky. Integrity problems due to the use of distributed databases and parallel processing are usually underestimated. Therefore, a consolidated roadmap to acceptance is required, even for the most simple automation tools, as well as ensured independence of acceptance and certification procedures. This is the more required to get general acceptance of ATC software modules.
- *Correctness and accuracy of the applicable models:* In many cases applied models are oversimplifications of the problems to be solved, as well as the applied strategy to solve a problem. The effect is that controllers can easily identify the cases where their own working method is superior to the method supported by the tools, with adverse effects. It is often underestimated how difficult it is to change working methods, or how unsuitable automatic procedures can be for human controlled operations. I.e. planning tools could be more successful if they would adhere to the working methods of the controllers.
- *Transparency, flexibility and ease of interactive access to new functionality:* Controllers make very few inputs to update a flightplan; their main task is elsewhere. Any tool requiring extra inputs and extra decision making to control the working of the tool, is a risk of an increase of workload.
- *Preservation of the control of the controller on the decision making process:* The time to transfer control from the controller to the computer has not come yet.

All advanced automated support to ATM, depends directly or indirectly on the quality to predict the aircraft trajectory in 4 dimensions (4D), and the capability to adhere to this trajectory. A successful way to exchange 4D trajectory planning information between the different actors of ATM is the basic functionality which determines the performance of all other automated support tools, and therefore, the first priority for ATC is to improve its capability to make flight predictions. Also all automated support tools within the ATC system are depending on the quality of prediction. A first step is to develop a purely ground-based trajectory prediction



function, a second step to accomplish air-ground integration and exchange of 4D trajectories. This second step will be a real challenge to solve all problems raised by inconsistency of modelling, data and software of all participating actors. (See Figure 4)

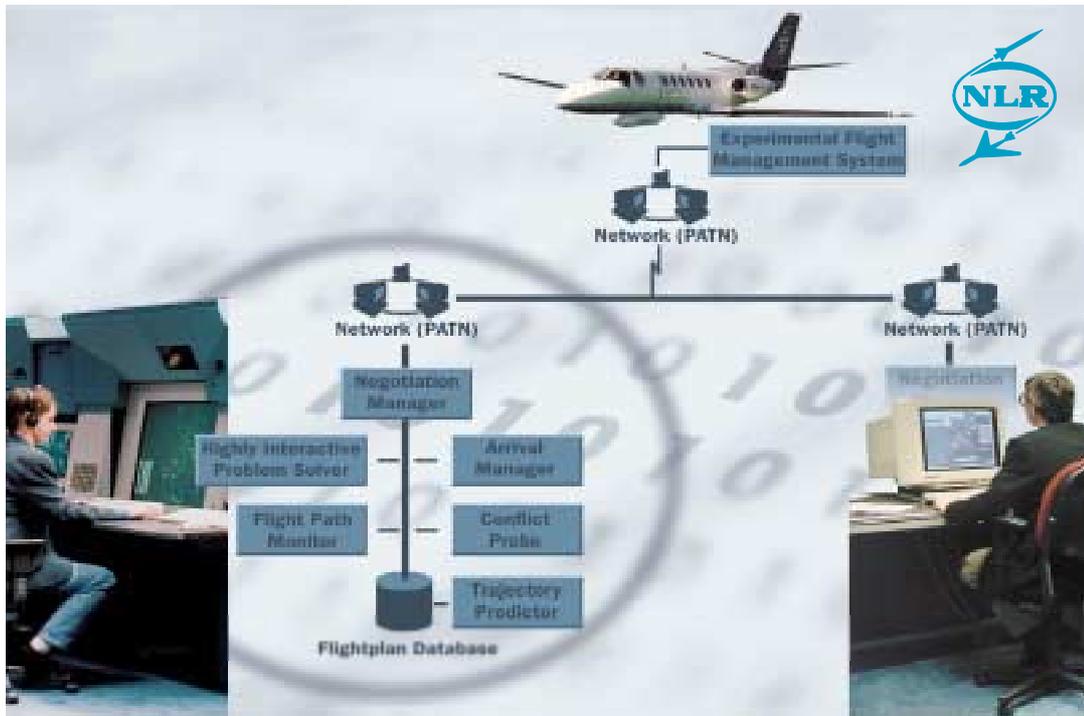


Figure 4 - Air-Ground integration, one of the most complex areas of ATM/CNS research

Conclusions

EATCHIP was a programme, running until 1998, which was successful to achieve a considerable enhancement of ATM in Europe. Its main achievements were to reach an equal, improved and harmonised level of support of CNS over large parts of the ECAC area. Very important was also the start of operations of the CFMU. EATCHIP has determined the current status of ATM in Europe and its successor, the EATMP, is now the main driver, formulating the current and future needs of an ATM for Europe.

The EATMP is a natural continuation of EATCHIP, but far more ambitious in its aimed achievements. The EATMP is based on an operational concept with a broad scope, comprising a Gate to Gate concept to plan and control a flight. This has far reaching consequences for the required interoperability between the different actors, as well as the requirements for



communication, information sharing and participation of the different actors involved in the process of decision making in ATM. The major concepts discussed in this paper are:

- *Airspace Organisation and Management*: To achieve an increase of capacity by a re-organisation and integration of use of airspace.
- *Flow and Capacity Management*: To improve flow management by refinement of planning and by increased dynamics and flexibility during tactical flow management.
- *Layered planning*: To “bridge the gap” with pre-departure flow management by extended planning, and to achieve an increase of capacity by shifting workload from tactical control to planning activities.
- *Free Flight*: To allow more flexibility in planning and execution of flights by introduction of free routing in en-route upper airspace, and to achieve an increase of capacity and flight efficiency.
- *Collaborative Decision Making*: To achieve better information exchange and participation in decision making by all actors involved, in all phases of flight, and to promote transparency of planning and control processes.
- *The role of the human in ATM*: To maintain the decision-making role and to preserve the situation awareness of the human actor. ATM relies ultimately on the flexibility and capability of the controller and the pilot to deal with exception handling, and this capability is still essential.

The experience with R&D the last 10 years and the crucial constraints imposed by the critical role of the controller in the ATM process makes that little progress has been made with the implementation of new functionality in the operational ATC systems. Nevertheless, advanced automation support is the only possible way that ATC can contribute to an advanced ATM system which provides the required benefits. Extended planning tends to demonstrate in this respect the most beneficial perspective.

The main requirements to be imposed on successful advanced automation support are:

- A good business plan with benefits to involved actors,
- Avoidance of over-complexity and a transition plan,
- Reliable, validated and certified software,
- Correctness and accurateness of the applicable models,
- Transparency, flexibility and easiness of interactive access to new functionality,
- Preservation of the control of the controller on the process of decision making.



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