Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

NLR-TP-2002-225

Collaborative flight planning in Europe
A contribution from NLR to identify operational concepts in ACARE

H.W.G. de Jonge and J.C. Terlouw

Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

NLR-TP-2002-225

Collaborative flight planning in Europe
A contribution from NLR to identify operational concepts in ACARE

H.W.G. de Jonge and J.C. Terlouw

This report is based on a contribution to the workgroup WP4-ST-1 of the Advisory Council for Aeronautics in Europe (ACARE).

Customer:	National Aerospace Laboratory NLR
Working Plan number:	L.1.A.1
Owner:	National Aerospace Laboratory NLR
Division:	Air Transport
Distribution:	Unlimited
Classification title:	Unclassified
	October 2002

Summary

"An improved flight planning process should be the heart of the future operational ATM concept for Europe, because good planning is the primary condition for efficient use of scarce resources and for improving punctuality of flights." This was concluded by ACARE/WG-4/ST-1 which is responsible for identifying operational concepts for the future European ATM system. This report elaborates this statement, by:

- describing the role of flight planning in the ATM process,
- proposing a generic model for the flight planning process,
- highlighting shortcomings of the current flight planning process, proposing improvements, and formulating the outlines of a roadmap.

The term flight planning is used for all planning activities by airspace users, airports, ATS providers, and CFMU, aimed at preparing movements of air vehicles. To be able to identify shortcomings and improvements, eight planning layers have been identified: Strategic Flow & Capacity Management, Pre-tactical Flow & Capacity Management, Tactical Flow Management, Departure Management, Ground Movement Operations, Departure in-flight operations, En route Flow Management, and Arrival Management.

Each layer is characterised by its own planning concepts and objectives. Furthermore, each layer has its typical scope of control in time and space, its critical points to cope with disturbances, and its own actors, responsible to realise the target settings and to optimise their planning. Most tasks can be considered as a joint multi-actor planning process. However, currently the collaboration between the actors is insufficient. Therefore, enhanced planning should be based on Collaborative Decision Making (CDM), with a clear division of responsibilities among all actors.

Improved flight planning asks for high accuracy and high modelling precision. The enhancements proposed in this report are therefore based on intensive use of 4D trajectory predictions. The options for improvements that are discussed cover the full scope of ATM planning, ranging from Strategic Flow Management half a year before the flight up to planning support to in-flight executive control. However, the most critical moment is just before the departure, because all actors in ATM are active simultaneously and appropriate decision making is the most effective. It is therefore, that the emphasis for enhanced planning is laid upon two of the proposed concepts: **Refined Flow Management** and **Departure Management with CDM**. The aim of these concepts is to be able to plan a punctual RTA (Required Time of Arrival) with a high confidence level before departure, because the potential benefits are the highest at that moment.

Abbreviations

ACARE	- Advisory Council for Aeronautics in Europe
AOC	- Airline Operator Centre
ATC	- Air Traffic Control
ATD	- Actual Time of Departure
ATM	- Air Traffic Management
ATS	- Air Traffic Services
ATSP	- ATS Provider
A-SMGCS	- Advanced Surface Movement Guidance and Control System
CDM	- Collaborative Decision Making
CFMU	- Central Flow Management Unit
EATMS	- European ATM System
ETD	- Estimated Time of Departure
FUA	- Flexible Use of Airspace
RTA	- Required Time of Arrival
SID	- Standard Instrument Departure
TMA	- Terminal Manoeuvring Area
4D	- 4-Dimensional
4D FMS	- 4D Flight Management System

Contents

(24 pages in total)

This page is intentionally left blank

1 Introduction

1.1 Good flight planning: the key to success

In most human activities good planning is the key to success. For example, the Euro could not have been introduced successfully without thorough preparation and flexibility in order to deal with unexpected circumstances. When it turned out that there were not enough small Euro notes available in some countries, it was possible to change the plan and provide these notes quickly, without disrupting the rest of the process. Probably the most important advantage of planning is that it allows to anticipate unexpected events.

For Air Traffic Management the same is true. A thorough and flexible flight planning process is crucial to meet targets of airspace users. For commercial airlines, these targets are derived from the objective to run a profitable business and therefore include punctuality, minimal fuel consumption, and maximum use of air vehicles.

In this paper the term flight planning is used for all planning activities that are aimed at preparing movements of air vehicles. It roughly consists of four main activities:

- Planning of individual flights by Operators (airspace users)
- Flow management by CFMU
- Planning of air traffic control by ATS providers
- Planning of ground and gate operations by airports

There are three reasons why flight planning is an important process in ATM. The first reason is that it is the only realistic solution to adhere to the customers requirement for punctuality. Although possibly less strict for cargo transport, at least all passenger transport has a fairly absolute and strict criterion to comply with punctuality in a satisfactory way.[1]

The second reason is that it is needed for efficient use of scarce resources, such as aircraft, ground systems and human operators. These resources are too costly to permit sufficient redundancy to be able to cope with weak planning. Furthermore, the amount of available

[1] The criterion for punctuality of a departure and an arrival is in the order of 5 minutes accuracy. Possibly the tolerance can be somewhat more for long-haul flights or charters, but the tolerance does not have to be much less, such as e.g. 10 seconds. If that order of magnitude is required in planning, it is only with the purpose to achieve separation of flights during tactically controlled executive operations, and therefore that measure of tolerance should be preserved for those conditions only.

resources can not be extended easily. This is clearly the case for airport infrastructures and available airspace.

The third reason is that good planning makes the ATM process robust against unexpected events, such as delays in loading, failing systems, disruption and changing weather conditions. In other words, planning is required to ensure sustainable throughput.

1.2 Purpose and outline of this document

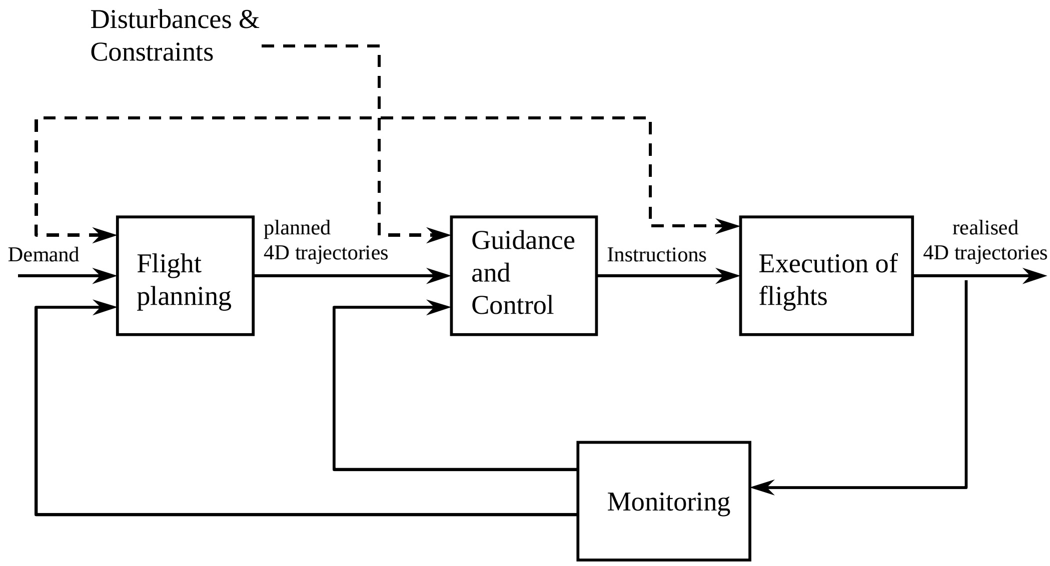
This document has been written for ACARE. It is a contribution to WG-4/ST-1, which has been responsible for defining operational concepts for the future European ATM system. During the second meeting of ST1 (Eurocontrol, January 8, 2002) it was concluded that an improved flight planning process should be the heart of the future operational ATM concept for Europe. This document is an attempt to reflect and elaborate the best ideas of the members of ST1 concerning this topic and is based on a number of references (see list of references). It explains the function and shortcomings of flight planning in the overall ATM process (Chapter 2), and identifies possible improvements (Chapter 3). Furthermore, since ST1 also concluded that improvements can only be realised via an evolutionary approach, some ideas are given about a roadmap to implement the proposed improvements (Chapter 4).

2 Function and shortcomings of flight planning in the overall ATM process

2.1 Function of flight planning in ATM

The objective of this section is to discuss a model of the ATM process in order to highlight the connection of flight planning with other main functions in ATM. The model, which is given in Figure 1, assumes that Air Traffic Management is a planning and feedback control process, consisting of four main functions: Flight Planning, Guidance & Control, Execution of Flights, and Monitoring. What isn’t clear from the figure is that ATM is in fact a highly complicated, time-dependent, dynamical, layered and converging process. However, for the purpose of this section the basic model of Figure 1 is sufficient. It will be discussed next.

The input of the ATM process is the demand of airspace users for displacements of air vehicles. The function of *Flight Planning* is to provide a consistent plan for a set of 4D trajectories (time and position), complying as much as possible with the demand of the airspace users, taking into account the constraints and disturbances affecting the overall process and the actual performance of the system. From the perspective of planning and control, it consists of strategic, pre-tactical and tactical planning both in the pre-departure and airborne phases of flight. An important aspect is the need for flexibility, as re-planning may be necessary, because of



Demand	= demand from airspace users
Disturbances	= unexpected events (weather, technical problems etc.)
Constraints	= constraints from regulating authorities on safety, noise, pollution

Figure 1 – The generic process of planning and control in ATM

disturbances to the process, such as bad weather conditions, technical problems, or unavailability of crew. Also disruption at a higher and more strategic level may occur such as an enduring decrease of capacity, e.g. experienced during the intervention in Kossovo. Furthermore, flexibility is required if during the process the demand of airspace users changes. A breakdown of the *Flight Planning* into subprocess is given in section 2.2.

The function of *Guidance and Control* is to provide instructions on the basis of which the flights are executed. The instructions are aimed at realising the 4D flight plans, by comparing them with the actual performance of the ATM process and by correcting for disturbances which haven't been taken care of by re-planning. Note that Flight Planning as well as Guidance and Control are processes that are performed on different levels by different actors, including operations by AOCs, CFMU, ATSPs, and pilots.

The function of *Execution of Flights* is to follow the instructions as closely as possible. The result is the output of the overall ATM process: the realised 4D trajectories. The execution of flights can deviate from the instructions because of various reasons, such as malfunctioning of systems, weather conditions, or miss-communication. This imposes uncertainty to the overall process.

Finally, the function of *Monitoring* is to measure the 4D performance of the ATM process. Monitoring takes place by many different organisations and with many different systems both in 'real-time' (e.g. by using surveillance systems, and communication systems) as well as off-line (e.g. post-flight analysis to measure the performance of the ATM system aimed at improving strategic planning).

A unique aspect of the ATM process is that a large number of actors are involved and have to work together. These actors can be divided into three groups. The first group consists of airspace users, including commercial operators, military users, and general air traffic. The main characteristic of this group is that it has demands for displacements of aircraft. The second group consists of civil and military Air Traffic Service Providers (ATSPs), CFMU, and airports. The main characteristic of this group is that it provides capacity and service. The third group consists of organisations representing society: the regulating authorities. The main characteristic of this group is that it puts constraints on the operations, mainly in terms of safety, emissions and noise.

The fact that these groups of actors have to achieve together the goals of the airspace users within the technical and social constraints is probably the most complicating factor in managing the process. The solution for dealing better with this complexity is to introduce a joint multi-actor flight planning process, with a clear division of responsibilities among all participants. To achieve this, it will be necessary to extend the planning and control performance capabilities of ATM by enhanced flow management and planning, starting from a European-wide scope.

2.2 Planning phases and short-comings

In this section we will zoom in to the *Flight Planning* process. Again the question is raised which model should be applied to describe it in more detail. It is proposed to use a model which roughly follows a scheme as presented in the EATMS-2000+ report [Ref. 1]. It divides *Flight Planning* into eight subprocesses converging in time and space (see Figure 2). This choice was made because this model incorporates all steps from strategic planning to tactical in-flight planning. It therefore represents the natural progress in time for both, the flight planning process as a whole as well as for the planning of individual flights. Another reason for choosing this subdivision is that it is quite generic and therefore most likely valid for describing the current as well as the future situation. Therefore, it is a good starting point to discuss improvements in an evolutionary way.

Next, each of the subprocesses will be discussed briefly by treating the main function and the most important shortcomings.

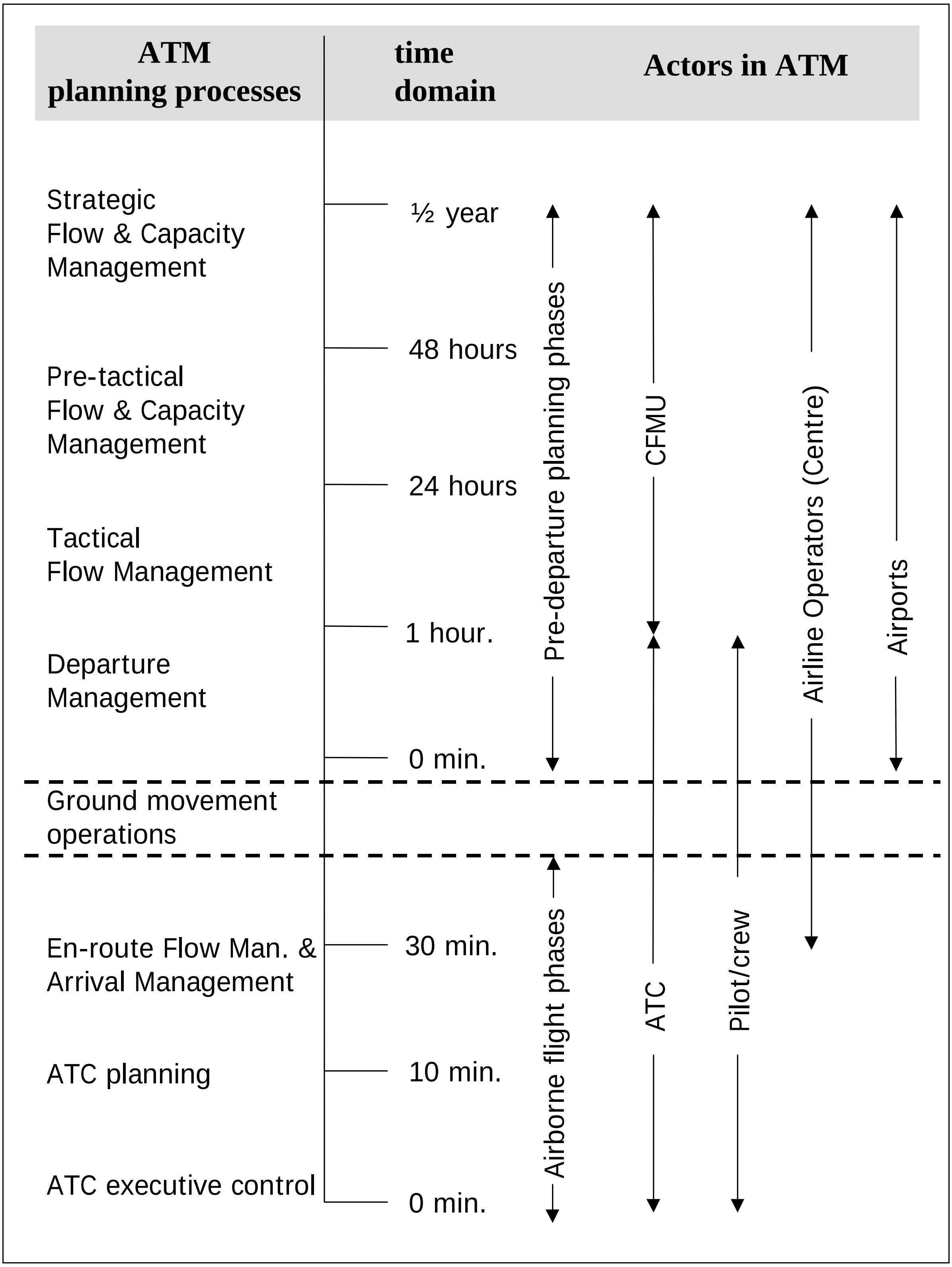


Figure 2 - A convergent planning process for ATM

Strategic Flow & Capacity Management: The process consists of slot negotiations for co-ordinated airports and a long-term forecast process by CFMU, aiming to predict the traffic load and the demand on airspace use for the next half year period. Directly related to this is a strategic Airspace Organisation and Management process aiming to ensure sufficient resources in terms of airspace and routing to provide the required capacity. There are shortcomings that can be identified because the present outcome of this process is not always based on all information available, and because all participating actors have their own changing interests and their own strategy changes.

Pre-tactical Flow & Capacity Management: Accomplished before the day of operations the objective is to anticipate the lately known expected conditions of traffic demand and available capacity. Also here, an Airspace Organisation & Management process can provide the required resources to enable capacity. The main shortcomings can be identified as lack of dynamics in allocation of airspace, stemming from a not yet optimal implementation of the concept of Flexible Use of Airspace (FUA).

Tactical Flow Management: This process aims to assign departure slots for each flight at least two hours before departure. It is based at one side on declared capacity by the ATS providers and at the other side on ICAO flight plans by the Operators. The objective is to prevent any sector in Europe from overloading by regulating these sectors when demand exceeds the available capacity. The tolerance of the slot assignments is 15 min. (-5 min, +10 min.). Currently, there is a lack of accuracy because planning is based on ICAO flightplans only. The mismatch in accuracy is large, because information on weather conditions, local conditions, aircraft modelling and detailed routing is not used by CFMU, while at the same time, the Operators' AOC is able to produce an almost perfect 4D planning, albeit without the knowledge of a precise departure planning. It is required for better planning consistency to bring together the modelling and prediction perfection of the AOC, the knowledge on bottlenecks, congestion, disruptions and flow behaviour of CFMU, and the knowledge on local departure planning and use of ground resources by ATC and the Airport authorities.

Departure Management: The slot assignments by CFMU are used by ATC to organise departure flows focusing on optimal use of runways, timely departures and airspace availability. The possibility for flights to adhere to 4D flight plans is heavily dependent on predictability of the actual departure time. In other words, the tolerance of the Actual Time of Departure (ATD), related to its Estimated Time of Departure (ETD), determines much of the capability to realise the plan. Currently, this is not always the case. Therefore, the take-off time has to be made better predictable and controllable in favour of better control on en-route and arrival traffic flows. In this sense Departure Management may create the conditions which makes it worth to perform Tactical Flow Management in the future with a higher level of detail than today.

Ground movement operations: Ground planning is tasked to avoid queues on the ground and to preserve safety. One aspect of enhanced accuracy and predictability of departure planning is that the quality of planning of ground operations has to be improved also. This may contribute to realise a precision of departures close to what could be achieved in a reasonable way, given the complexity of operations of ground movements on a busy hub airport. The integration of planning of departure ground movements with arrival ground movements, however, will ultimately maintain a highly tactical process in spite of precisely planned departure ground movements.

Departure in-flight operations: The take-off as well as the initial climb are flight phases that are highly tactical by nature, only after completion it can be considered how actual flight execution relates to its planning.

En-route Flow Management, planning and control: En-route planning has the scope of control of a sector and/or a centre/FIR, and has the objective to ensure separation (safe, efficient and orderly). Once in-flight, it is difficult to decide on deviations from the planning and how to react optimally. To return to the original planning may be inefficient, or even not feasible (too much delay), and, when tightly planned, it may be unfavourable to miss the planned arrival time. Problems related to local traffic situation conditions can be judged and solved by ATC only, tactical operational flight conditions can be judged only by the pilot, and economical consequences of potential delays are subject to decision making by the AOC of the Operator. ATC is able to decide on the short and medium term planning and control conditions, but is not able and not committed to decide on the best and most efficient changes on planning for the remaining flight. The AOC is the only actor in position to judge the arrival conditions at a possibly congested destination in relationship to economical considerations forthcoming from deviations. Therefore, improvement of flight planning should take into account the roles and tasks of the actors involved.

Arrival Management: The arrival planning has the objective to make optimal use of available runway capacity and, within its limitations, to avoid holdings. It is a metering and sequencing process, which is by nature highly tactical, even if it may start already about a 100 miles out (which is today not the case for many airports). Nevertheless, its planning aspect is extremely important given the strong constraints on achieving separation on the runway and making maximum use of the available runway capacity. A shortcoming is that the flows of arriving traffic are not always stable and not always distributed equalised over time. This will require an early regulation of departures in order to be able to plan a Required Time of Arrival (RTA) with sufficient ensured capacity at destination to arrive in an punctual, undisturbed and efficient way.

Summary of shortcomings of the current flight planning process

The shortcomings of the current flight planning process can be summarised as some elementary problems that are inherent to processes in which several actors have to achieve together common goals, while working geographically at different locations, speaking different languages, and most importantly having different responsibilities and objectives:

- The actors have insufficient access to information to analyse problems and to select preferred solutions for their problems,
- Furthermore, insufficient options are available to be able to select alternatives,
- Planning decisions, that are dependant on each other, are not brought together timely,
- Planning decisions are not always made by people in the best position to take these decisions.

As a consequence a mismatch can easily occur in all different phases of Flight Planning described above. This may result e.g. in mismatches between demand and the outcome of negotiations on airport slot assignments, the estimates on expected traffic flows, and the available routing capacity in the Strategic Flow Management phase. A good example is the departure phase in which AOC, CFMU, crew, ATC and airport authorities have to work together (see also Figure 3):

- AOC initiating and planning the flight,
- CFMU generating the departure slot,
- The crew, doing flight preparation,
- ATC, planning ground movements and the estimated time of departure,
- The Airport authorities, delivering the services such as the push-back and controlling platform operations.

Currently, these different actors are taking critical decisions, while not all the information on timing is made available at the right moment to all people involved in the process.

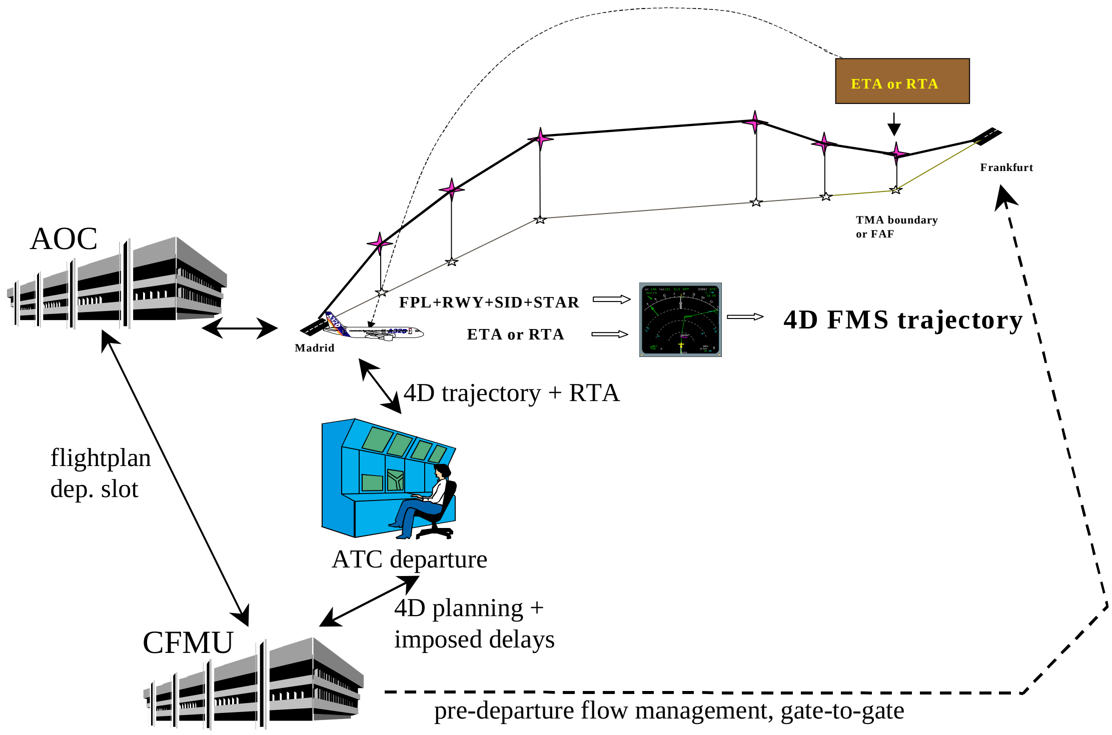


Figure 3 - planning and co-ordination around the departure phase

3 Proposed enhancements for European flight planning

A set of enhancements of the concepts for flight planning are discussed in this chapter. First some aims and conditions are listed that can be considered as setting the scope and constraining the context in which these developments could take place. Thereafter, the proposed enhancements are discussed following the same structure of planning layers in ATM as described above in section 2.2.

3.1 Aims and conditions

The aims to develop an extended and adapted concept for layered flight planning and some of its basic constraining conditions for successful implementation, are:

1. It must be based on a clear division of tasks and responsibilities and must respect competencies in decision making, in particular the tasks of the ATS providers to maintain safety and to comply with imposed environmental restrictions.

2. It must be based on collaboration, because this will allow each airspace user, service provider and airport to influence planning decisions for their own and common objectives. In addition it will have to be beneficial to optimal deployment of capacity, and it will have to be efficient and safe in executive operations.
3. It must be convergent in space and time. In other words, the level of detail and freedom to change routes, departure and arrival times should be appropriate for the particular planning phase at hand. Unnecessary constraining conditions should be avoided and flexibility should be preserved as long as possible.
4. It must allow the strategic flow management process to start (as today) from a European-wide scope. The reason is that there is coherency and dependency of airspace use, performance of flights and use of airport resources within Europe. Flight operations outside Europe are a minority (10% to 15%), and these are most long-haul flights. Further, it will be feasible to incorporate in particular the arriving flights timely into a European-wide Flow Management process, while at the same time the tolerances for planning precision of these flights can be possibly somewhat larger.
5. It must be secure, in the sense that requirements of information provision must take into account the interest in confidentiality of its users.
6. Also constraints, stemming from National security requirements, are to be respected.

(See also Ref. 1, EATMS-2000+, Vol. I)

3.2 Improvements of flight planning in ATM

A concrete set of planning improvements for ATM is discussed now, starting from the earlier discussed layers of planning (see section 2.2). The same major planning layers are addressed now again.

3.2.1 Strategic Flow & Capacity Management

Re-organisation of airspace: Airports, their rigid infrastructure and their modest growth scenario, form the basis to optimise airspace organisation and to provide the capacity to cope with the demand. Sufficient airspace to feed arrival traffic to the airports is a primary requirement to be able to provide Arrival Management service provision in a successful way. Where necessary and closely allocated, groups of airports can be served the best by one ATS provider, such as e.g. in the London TMA. A ‘single European Sky’ is needed in the sense that national boarders should not constrain efficient use of airspace.

Optimisation of route network: En-route use of airspace can be improved by servicing basically point-to-point city-pair route connections and by optimising the Flexible Use of Airspace (FUA) concept to dynamic use of airspace according to the need of individual flights.

Demand and capacity forecasts: The strategic planning to balance use of airspace and airport capacity is to be considered as an integrated CDM process for airspace users, ATS providers and airports by co-ordinating on airport allocated slots, calculated slots and operator schedules. The forecast can be improved by a more pro-active planning process and by combining an extrapolation of performance data from the past with forecast of the demand by airspace users and airports [Ref. 3].

3.2.2 Pre-tactical Flow & Capacity Management

Dynamic demand and capacity management: An Airspace Organisation & Management process can be used to provide the required resources to enable capacity. Consequent application of the concept of FUA offers good means to manage airspace capacity. Accomplished before the day of operations, the objective is to anticipate the lately known expected conditions of air traffic demand and to make capacity available, as required.

Enhanced periodic Pre-tactical Flow Management: Pre-tactical flow management is tightly coupled to the strategic process. It is a one week, cyclic process with a strong reproduction pattern. It can last up to 5 hours before departure.

- *Optimise local capacity*: To improve the co-ordination between CFMU and local ATC on the most effective use of local capacity.
- *To improve the use of FUA (Flexible Use of Airspace*): FUA should be focused on use of airspace that allows Airline Operators to make use of it in their planning. Too much airspace is still dedicated to mainly military use.
- *Optimisation of sector configuration*: The capacity can be enlarged by increased use of dynamic sectorisation, and by dimensioning sector configurations to the demand.

3.2.3 Tactical Flow Management

Flexible slot management: Tactical Flow Management is a typical multi-actor process, and as such it can be identified as appropriate for CDM applications [Ref. 3]. Interactive access for all actors to all essential planning information available is of paramount importance. Further, increased flexibility is required, identified as CDM applications like slot shifting, slot swapping and slot substitution [Ref. 3].

Refined flow management: There are great opportunities to improve the quality of planning by using 4D trajectory predictions. The aim with respect to Flow Management is to come to a 4D planning before departure with an ensured capacity to perform an undisturbed timely and efficient arrival at destination. AOC will be able to submit a flight planning before departure with much of the precision of a full 4D trajectory. When this information is incorporated in a European wide Refined Flow Management process, this will allow a CFMU to perform its process of Flow Management with high accuracy, reliability and a high confidence level, while at the same time the competencies of all actors involved in flight planning, can be preserved. The quality of Refined Flow Management can be enlarged by making effective use also of in-flight planning updates. The result of the Refined Flow Management process is merely to submit departure time constraints for flights to congested destinations. Departure constraints are to be considered as the accepted penalties in exchange of workload reductions and efficiency gains in the in-flight en-route and arrival flight phases.

Improvement of implementation of process of Tactical Flow Management:

- *Improved slot allocation algorithm*: The objective is to minimise delays. There are better algorithms than the presently applied first come, first served algorithm. However, such an algorithm should not only serve to increase the capacity, but should be also operationally acceptable.
- *ETFMS, surveillance*: The first stage of ETFMS should result in providing surveillance information. This allows to make use of in-flight information to update the data repository, used to derive the assignments of departure slots to not yet departed flights.
- *ETFMS, data provision*: To improve informative data provision on data flows to allow airline operators to select optimised routing.
- *What-if routing by CFMU*: To improve 4D prediction capability and the quality of available aircraft models and data. The objective is to allow CFMU to optimise their capability to offer alternative routings to operators.

3.2.4 Departure Management

Departure Management and CDM: Departure Management is a well-known planning process that has to cope with constraints imposed by Flow Management, but also with all other kinds of constraints such as e.g. delays, services and loading problems. As such, it is a typical multi-actor planning process, basically dealing with departure sequences and efficient use of runways and SIDs. Given the multi-actor back-ground of pre-departure flight planning, Departure Management is a good candidate for extensions with CDM-like interactive planning and information provision features.

CDM and enhanced CTOT calculations:

- *Enhanced CTOT*: CFMU to be informed on enhanced CTOT estimates by ATC.
- *In-flight planning updates*: CFMU to be informed directly after take-off and on flight plan deviations on updated flight planning and CFMU to re-distribute this planning.
- *Ground-ground trajectory exchanges*: To exchange trajectories (4D planning) between CFMU and ATC and between CFMU and Airline Operator.

- *Databases*: To develop a database for in-flight status information (flightplan data and surveillance data) and a database for airspace usage.

Planning of ground operations: The performance requirements on Departure Management become more severe due to the requirement of high precision on actual departure times (take-off) as result of enhanced planning accuracy by Refined Flow Management. One source to improve this performance level is what is under development under the header of an A-SMGCS. The A-SMGCS itself is considered here outside the scope of describing 4D planning concepts.

High precision take-off planning: When Refined Flow Management and Departure Management are able to realise a planning precision of actual departures with a tolerance of roughly 1 min., determined further by different flight-dependent conditions and the appropriate performance level of the A-SMGCS, then this can be the starting point for enhanced accuracy of in-flight planning and control.

3.2.5 Ground movement operations

Ground movement operations are typical sources for disruption of planning. Re-planning comes later.

3.2.6 Departure in-flight operations

In-flight departure operations are highly tactical and flight performance is sensitive for deviations. The opportunity to correct the planning for deviations is after this flight phase.

3.2.7 En-route Flow Management, planning and control

Flight re-planning and CDM: Re-planning the remaining flight up to destination is required if a significant deviation is detected from the planned Required Arrival Time (RTA). Given their interest, an improvement would be to involve AOC in decision making. This can be identified as a CDM application between ATC and AOC via the pilot.

Multi-sector and multi-centre planning: 4D planning makes sense if the planning horizon can be extended and if early anticipation enables to react on local disturbances of flows or when the capacity is exceeded. An extra planning layer is required.

4D-planning: The exchange of 4D planning information between air and ground may tighten ultimately the control loop in very significant way. This can be beneficial in terms of enhanced precision of planning and improved deployment of available airspace. The improvements for guidance and control can be significant, but the impact on current roles, tasks, and procedures is significant, too. However, a step-wise introduction can be considered to reduce risks.

3.2.8 Arrival Management

Equalising arrival flows: One of the most important benefits from enhanced planning can be obtained by equalising the demand over time. The objective is to minimise bunching effects on arrival flows and to maximise stability. The primary process to arrange equalised arrival flows is Refined Flow Management, but fine tuning may take place in the arrival management phase by exchange of capacity changes and planning information and by co-operation in planning between ATC centres and CFMU.

4D-guidance in the arrival phase: Arrival Management can be enforced with respect to accuracy, predictability and punctuality by using a closed loop 4D guidance process in adherence to 4D planning. Given the impact on procedures, roles, tasks and safety, this has to be developed and introduced in a step-wise and long-term development process. However, once operational, significant benefits can be expected. One result can be that 4D guidance and control may enable environmental friendly continuous descent approaches, while maintaining a tightly sequenced arrival flow at the same time.

4 Roadmap to improved flight planning

It is over-ambitious at this stage to define a detailed Roadmap for development and implementation. Nevertheless an attempt can be made to formulate a global and high level transition path, by formulating criteria to determine priorities, and thereafter to formulate a high level ordering of three main phases for implementation.

Three criteria have determined the priorities in the roadmap given below. First of all, any proposed development and implementation step should provide early benefits, in particular to reduce delays and to increase efficiency. Secondly, a proposed development and implementation step should fit in a natural, incremental and evolutionary development programme. Thirdly, preference should be given to implementations with low risk and a low impact on safety. An essential element to achieve this, is not to change competencies, roles, tasks and responsibilities of participating actors, and in particular not to affect roles of executive controllers and pilots. Also developments that can be implemented within a local context without strong dependencies between organisations are preferable. Based on these criteria, the following high level ordering of activities can be identified:

Step 1: to implement Refined Flow Management with support of improved Departure Management. The most striking mismatch between planning and realisation stems from departure delays. Potential solutions can be found in CDM, improved Departure Management and Refined Flow Management. A most significant deficiency in planning was identified from the weakness of the output of Tactical Flow Management. Refined Flow Management can improve the quality of planning significantly with low risks and high benefits. Improved Departure Management and CDM in support of departure preparation and the realisation of accurate departures, are the enablers, required to improve the quality of flow management planning data. The implementation can start from AOCs' planning and a CFMUs' implementation of an enhanced flow management process.

Step 2: to extend 4D planning with informative coupling of air and ground by datalink. Tightly coupled to enhanced planning, is the ability to use the planning data as guidance information for realisation. Benefits can be expected therefore by achieving consistency in applied planning information at the executive level. Therefore, the next logical step is to equip aircraft with a 4D FMS and to require that ATC is able to uplink planning constraints in order to achieve consistency in planning. However, it will not be required that ATC will use uplink information as executive instructions. It can be expected that controller and pilot working with accurate predicted planning data, will be successful on own initiative to make beneficial use of these data, and as long as controllers are performing their executive roles in a traditional way, the risks in terms of hazards and safety can be fairly low.

Step 3: to extend 4D planning with first use of 4D guidance. 4D guidance can become as precise and accurate as required to maintain separation when the control loop is refined, which means that certain control features are solved in an air-ground integrated way. This can be beneficial in terms of workload and accuracy. It implies to make use of the 4D guidance capability of the aircraft, and to abandon certain control functions by the pilot and/or the controller. Of course, this has a heavy impact on working procedures and safety, but implementation in small steps with limited impact should be considered feasible.

Much of the potential benefits of enhanced planning are dependent on Strategic Flow Management and Airspace Organisation and Management. This process has its own dynamics and it should get priority therefore. However, it is preferred not to give it a number in the sequence of the roadmap given above.

There are well-known strategies to follow a roadmap for development and implementation, reaching from early prototyping to operational shadow-mode trials. It is here not the place to discuss this topic in detail. Rather a few issues can be raised that might deserve special attention in the coming years:

- Advanced algorithms, operating under operationally realistic conditions, will require high attention. These algorithms have to be robust, reliable, sophisticated and transparent.

There is a need for validation and verification of algorithms, separately from software implementation. Examples are: Flow Management, Departure and Arrival sequencing and Trajectory prediction.

- There is a need to come to sophisticated large-scale fast-time simulations, working on advanced planning concepts. On the one side, much progress is made the last years with obtaining quantitative results from fast-time simulations, on the other side, these facilities are not yet equipped to simulate also advanced planning models. Given the discussion before, and the need for reliable quantitative cost-benefits assessments, this point might deserve specific attention.
- A considerable effort has been spent the last 10 years to develop a standard for a European Controller Working Position platform. There is strong suggestion from experience that the standardised platform will ultimately not satisfy all the requirements of all potential users. There might be a need to introduce more flexibility in the architectural design of a real-time prototyping platform, and to discern e.g. specific layers with algorithms, with basic tool functions and environmental specific filtering layers, and to allow certain freedom in HMI design. This might create a powerful area of research, aiming to increase the potential for acceptance by the users of advanced ATM functionality.

5 Conclusions

This paper has highlighted the important role of planning in ATM, and has identified opportunities to develop and implement a set of significant enhancements to planning. The proposed set of enhancements ranges from short-term implementations with low risks to long-term implementations with a much deeper impact on roles and procedures of the actors in ATM. However, all proposed planning enhancements are characterised by offering a high level of confidence that they will provide benefits in terms of punctuality, capacity and efficiency.

The discussion around planning concepts aims to make clear that a major point of enhancement is to enable all actors active in ATM to be informed timely of planning updates and to participate in planning processes where their interest is and where they are in the best position to take a decision. Planning is essentially a multi-actor process with different layers of planning accuracy and planning commitments. Further, planning has to be tuned tightly to plan as precise as the flight preparation process permits and requires to make planning commitments.

The most critical moment of planning is just before the departure. All actors in ATM are active simultaneously, the consequences of miscommunication and planning inconsistencies are the largest, and appropriate decision making is the most effective. It is therefore, that the emphasis for enhanced planning is laid upon the concepts for Refined Flow Management and Departure Management with CDM. The aim is to plan a punctual RTA with a high confidence level before departure.

References

1. Anon., EATMS ATM Strategy for 2000+, Eurocontrol, *ref. EATCHIP Doc.: FCO.ET1.ST07.DEL02, Proposed Issue 2.0,* Brussels, May 1998.
2. Anon. ,Operational Concept Document (OCD), Eurocontrol, *ref. EATCHIP Doc.: FCO.ET1.ST07.DEL01, Edition 1.1*, Brussels, January 1999.
3. Peter Martin et al., Potential Applications of Collaborative Planning and Decision making, Eurocontrol, *ref. EEC Note No. 19/98*, Brétigny, September 1998.
4. Hugo de Jonge, An Operational Concept for 4D Air-Ground integrated operations, A concept for strategic 4D flight planning with potential for short-term maturity, NLR, *ref. to-be-published,* Amsterdam, 2002.