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Free flight in a ground controlled ATM environment

W. Post and H.W.G. de Jonge

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AUTHORS W. Post and H.W.G. de Jonge	DATE 971127	pp 15	ref 18

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ABSTRACT

"Free Flight": The buzzwords of the recent years. They usually apply to the users of the airspace system, the airline operators and the aircraft. It does not indicate that flying is for free now, but that the users should be as free as possible in their operations. They can take-off from where they want, land where they want and take any route in between. And they should be able do do so whenever they want it. Now, it does not require a great deal of imagination to see that this will not always be possible for everyone. Some resources in the ATM system (especially runways) are so scarce that their use is restricted in some ways. In order to allow equal use by all users there will thus be a continuing need for a ground based ATM service. This paper tries to point out where the balance may be found.

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FREE FLIGHT IN A GROUND CONTROLLED ATM ENVIRONMENT

Ir. W. Post and Drs. H.W.G. de Jonge, NLR, The Netherlands

“Free Flight”: The buzzwords of the recent years. They usually apply to the users of the airspace system, the airline operators and the aircraft. It does not indicate that flying is for free now, but that the users should be as free as possible in their operations. They can take-off from where they want, land where they want and take any route in between. And they should be able to do so whenever they want it. Now, it does not require a great deal of imagination to see that this will not always be possible for everyone. Some resources in the ATM system (especially runways) are so scarce that their use is restricted in some ways. In order to allow equal use by all users there will thus be a continuing need for a ground based ATM service. This paper tries to point out where the balance may be found.

1. Introduction

Ever since the FAA came out with their new ATM concept ideas under the heading “Free Flight” everyone has had different views on its definition. The airline users had their own ideas on the amount of freedom they would get in this new concept. The ATM service providers in turn had their own ideas on how much freedom they would give to the users. Whatever the final definition of this freedom will be, the essential message of the concept is that it aims at taking away any unnecessary restrictions on the users so that they can run their business the way they want. As such the concept development is mainly driven by the need to increase system flexibility and efficiency. The freedom that can be achieved in the end can not be foreseen yet. However it is clear that in some ways limitations of this freedom will still be applicable.

In Europe, ATM concepts developments have already started quite some years ago. Usually the work of the GARTEUR group is mentioned as the initiation. What followed were studies and programmes with names like: FEATS, EASIE, ATLAS, AEGIS and EATCHIP (EATMS) [Ref. 1,2,3]. Also there was the European contribution to the ICAO FANS CNS/ATM concept. One of the later programmes is called Programme for Harmonised ATM Research In EUROCONTROL (PHARE) [Ref. 4,5,6,7]. In this programme a concept line has been elaborated to the extent that it can be demonstrated in real-time ATM simulations. The driver for the development of these European concepts has always been the foreseen increase in demand in comparison to the limited capacity available. As a second level objective the aim is to increase system efficiency and overall system safety has been set as a boundary constraint.

In 1996 co-ordination has been initiated between FAA [Ref. 8,9] and EUROCONTROL on the developments of their operational concepts. The exchange of ideas is starting to occur and both parties are closely monitoring each others developments.

Based on these various operational concepts [Ref. 2,3,6,7,10], this paper is aimed at identifying the balance that exists between capacity, flexibility and efficiency in relation to the freedom that can be given to the users. It sets out some discussions on concept directions that could be most promising in fulfilling all requirements best.

In the next section it is elaborated in more detail how airports form a major restriction in the system and how they influence concept developments. In the subsequent section called “Predictability and convergence” it is discussed what role predictability plays in the world of ATM and especially how it relates to overall system convergence. The next section is then devoted to “Flexibility”. It discusses the kinds of flexibility that may be required and the autonomy that can be granted. The question is raised which role and which flexibility is allowed to autonomous aircraft operations. In the following section called “Extended planning” the conditions are discussed that make an extended planning concept to a success. It is explained how the aircraft is able to contribute, using its 4D capability to support the confidence of a planning process. Finally, the concluding section aims to give a clarification of a concept direction that could take into account all pros and cons discussed before.

2. Airports are the bottleneck

In the early days of flying the pioneers usually prepared their own special take-off and landing field. These could be located anywhere. When aircraft became more and more used for passenger transport airports were built less arbitrarily in the neighbourhood of large and medium-sized cities. Over the years some have grown rapidly to become major airports, others have been developed to regional airports. They are usually located quite conveniently close to populated areas that have also grown over the same time. As a result of this 'natural selection process' one can now consider that in most western countries the locations of the airports are fixed. What is less fixed, however, is the way air traffic is developing around these airports.

With the growth of air traffic of the past decades also the airports have grown. This growth was usually reflected in increasing numbers of gates to service aircraft, extended runway lengths to cater for larger and heavier aircraft and larger terminal buildings to accommodate the passengers. What has changed less is the number of runways at each airport. They usually provided sufficient capacity to handle the traffic, but the way they were used changed drastically.

As demand for air traffic has kept increasing it can be observed that airport capacity is often used to its maximum extent. Ignoring all complex management processes around passenger and luggage handling, gate-handling, and ground handling services, the attention in this paper is focused on the air traffic control side of the problem.

There is some evidence in fact that with slowly increasing runway capacity, specifically the major airports in the core area of Europe will hardly be able to serve the increasing demand. This becomes clear, if the annual number of movements are considered for some typical major airports (see table 1, [Ref. 11,12,13]) and if it is taken into account that most of these airports have usually two to three runways available to be used simultaneously for arrivals and departures. The need to support traffic peak periods and the need to avoid night traffic, are basic limitations to fully exploit the capacity, which leads to frequently observed congestion in arrival and departure traffic.

Country	Airport	No. of passengers	No. of movements
Belgium	Brussels-Zaventem	12.5 million	245000
France	Charles-de-Gaulle	Total Paris area: 59 million	360000
	Orly		250000
Germany	Frankfurt	39 million	378000
	Düsseldorf	15 million	-
	Munich	14 million	200000
Netherlands	Schiphol	28 million	340000
UK	Heathrow	Total London area: 85 million	420000
	Gatwick		210000
	Manchester	15 million	160000

Table 1 - Present-day (1996) loads of air traffic at some of the major airports in the core area

Solutions for solving shortness of runway capacity are limited. Constructing new runways is difficult and time consuming because of all the political and social hurdles that have to be taken. Constructing new airports is, given the environmental constraints and the infra-structural limitations even more a question of the far future. In the mean time the demand will be regulated, or should regulate itself, which will lead to a further spreading of arrival and departure peak periods, and which will lead to a shift of traffic load to regional airports with a less overloaded capacity profile. As unavoidable as this is, it will also be unattractive to some parties and it is certainly in contradiction with the expressed wish to enable Free Flight.

To some extent, a feasible alternative will be to use the available runway capacity more efficiently, where capacity falls short. This can be achieved by reducing the actual separation to the prescribed minimum, by avoiding gaps during peak hours, and by organising arrival and departure flows in order to achieve optimised flows with respect to the sequencing of weight categories. Essential hereby is that actual runway occupancy time as well as the interval between successive occupancies is always as short a possible.

It will be clear that in order to make maximum use of available capacity it needs to be carefully planned. Again this may lead to a contradiction with Free Flight because a consistent planning process limits the freedom to change flight execution.

In the following sub-sections the basic conditions for planning departure and arrival traffic are reviewed as well as their dependency.

2.1 Planning departure traffic

When departure traffic is planned, its **objective** in relation to optimised runway use is to have an aircraft available at the holding point at any moment that the runway becomes available for departure traffic. The way in which this objective is achieved also depends on the priority that is given to **some other objectives** like:

1. That aircraft will be enabled to realise their departure as close as possible to the schedule.
2. That there is a need to use each available slot. If it is not used, delays and congestion may be caused.
3. That passengers, pilots and aircraft's waiting time up to and at the holding point is minimised.
4. That he Airline Operator is not obstructed in his freedom to adapt the departure planning.
5. That a minimum of noise is produced by the departing aircraft

The overall success of departure planning relates to the balance that can be reached between the achievement of each of these objectives. In trying to do so some problems are encountered. Normally, departures will not be re-planned to a time before their scheduled departure time. This creates a one sided bias. Also, excessive delays with respect to the schedule are very undesirable. At the same time, extensive flexibility is expected for events that occur very frequently in practice, like late passengers etc. Finally, when the take-off is to take place actually within the assigned slot, the uncertainty of the actual departure time is still an order of magnitude larger than what is expected for accurate en-route planning.

From the above it is clear that departure planning is a difficult process that interacts at several layers of the ATM process. It is a continuous struggle to use every available departure slot whilst at the same time allowing for the desired flexibility for the aircraft operators.

2.2 Planning arrival traffic

The **primary objective** of planning an arrival flight is of course to assure a safe, expeditious and orderly descent. There are also **other individual objectives** for planning arrival traffic:

1. timely arrival of each flight,
2. avoiding holdings,
3. optimal efficiency of flight performance, what is a more subtle objective than to avoid holdings,
4. minimal noise & pollution, e.g. by a continuous descent approach,

These individual objectives do not automatically result in a maximum use of the available arrival capacity. They are therefore subjective to **some collective objectives**:

1. efficient use of limited TMA airspace capacity,
2. optimal use of landing capacity.

It is clear that trying to fulfil all of these objectives in an acceptable way will always result in a balance between the individual and the collective objectives.

Current arrival management tools, such as CTAS [Ref. 14,15, 16], ZOC, MAESTRO, and COMPAS [Ref. 16] are all focused on tight metering, attempting to reach a minimal landing interval rate. Planning distances up to 200 NM, over a period up to 40 minutes are used.

Basically, these tools can regulate and merge different arrival flows for one or more runways, however, they can handle these flows only well, and e.g. avoid holdings, if the maximum arrival capacity is not exceeded for too long. A management process of flow regulation is a prerequisite to prevent these overloadings.

Specific for the current tools is also that they are based on an ‘open-loop’ view of the world. Behaviour of arrival flights is predicted up to a certain extent, but there is no guarantee that these predictions are correct. These tools are therefore not only correcting continuously for unpredictable events, but also for their own prediction inaccuracy.

There are definitely ways to improve the effect of arrival management and to optimise its results, compared with the current arrival management tools. A first step could be to close the loop by enforcing consistency on trajectory prediction in the air and on the ground, and the use of 4D guidance to support accurate flight conformance to what was planned. However, built-in flexibility will be required for exception handling and efficient use of landing capacity, and should be applied in the accompanying procedures.

Apart from all aircraft specific modelling aspects, arrival management is subject to apparent phenomena of queuing behaviour. And because the aim is to increase the capacity to its maximum, it is quite sure that operations will tend to encounter the well-known critical behaviour of such queues. This means that arrival sequences can become unstable when they become critical for feed-back effects. Those effects will then tend to manifest themselves on the tactical level, where unplanned actions cause the disturbances. It is therefore concluded that a regular, balanced supply of arrival traffic is essential for successful planning on dense arrival flows. Moreover, the capacity planning is essential and should be based on a sub-critical level of the expected sequences. Modifications to the planning will still be possible but should preferably occur by re-planning instead of ‘just-doing’. Finally, spare capacity is essential given the behaviour characteristics of critical sequences. The tighter the sequences, the more important that the tactical controller is able to react and has some freedom of manoeuvring left over.

Optimal arrival management asks from the aircraft to follow their planning as long as possible and as close as possible. Optimal flight performance with respect to efficiency and economy, however, requires flexibility to adapt the planning. An optimal balance, between overall capacity and individual flexibility, can be achieved only, if both aspects are taken into account continuously in each decision.

2.3 Interaction between departure and arrival traffic

Above, arrival and departure planning have been described separately. In this section it is described how departure and arrival planning relate to each other (see Figure 1).

First, **departure and arrival planning at one airport** are coupled by shared use of resources: aircraft, runways, taxiways, gates and airspace. Arriving aircraft will land, taxi to a gate, unboard and board passengers or freight, taxi to the runway and take-off again. The operator’s schedules, the passengers schedule, the available gate, runway and airspace capacity link everything together. Disturbances on arrivals can easily affect departures and vice versa.

Secondly, **arrival planning and departure planning at different airports** are interacting because of the highly optimised flight profiles in between, which allow only for very little uncoupling. In combination with tight schedules of the operators effects can easily build up over all the flights that individual aircraft make during the day.

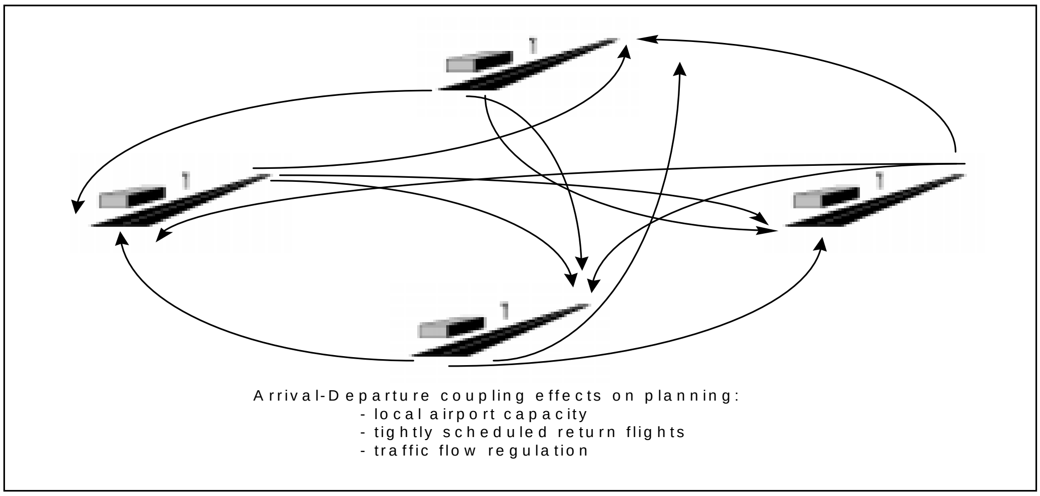

Figure 1 - Interaction between arrival and departure traffic

With respect to **traffic flows**, there are even more coupling effects. Delays and deviations often tend to have a systematic rather than an individual effect. This concerns e.g. weather effects and delays originating from congestion effects on overloaded airports.

Altogether there are enough interactions in the system to cause enormous knock-on effects, which proceed through the entire area or through groups of airports. It is quite evident that an increased amount of traffic and high density traffic flows will cause more pronounced knock-on effects. The more critical the density of flows the more visible and the more excessive will be the accumulation of delaying knock-on effects. This is different from the traffic jams that we can experience daily on the roads, where knock-on effects play virtually no role, because it concerns almost only simple departure to destination traffic.

The numerous ways individual flights and flows are bound to each other, causes the traffic in high density traffic areas with large numbers of airports to be heavily interdependent. With an expected increase of traffic these effects tend to be enforced more than proportionally.

What is attempted to demonstrate here is the strong interdependent complexity of flight planning and flight performance in dense traffic areas, working close to their maximum capacity, and the required mechanisms to keep control on traffic flows. Instability due to feed-back effects of coupled processes are to be mastered. In this light one wonders what freedom there can be for the individual players of the game.

3. Predictability and convergence

Extended flight planning makes sense only if it is possible to rely on accurate flight prediction. The value of flight prediction depends on the quality of flight performance in conformance with the prediction. This flight conformance requirement restricts flexibility and the freedom to take initiative. Convergence of a planning process by step-wise refinement, is the way to provide the compromise between extended planning on one side and flexibility and freedom on the other side.

3.1 Predictability

As explained above, ATM is an extremely complex process with lots of sub-process, interactions and non-deterministic inputs. The status of the total system, or its individual elements, can therefore not be predicted accurately. The difference between the prediction and the status can be compared to a complex wave, that is built up of a number of unknown sub-waves, which each have their own frequency, amplitude and other characteristics. In order to converge to a situation where in the present time the status is known (and safe) each layer of the ATM process tries to analyse its own frequencies and eliminate them from the prediction. Strategic Flow management e.g. looks at traffic flows (larger amplitude) over a long time (low frequency), whereas tactical control looks at individual aircraft (low amplitude) at short term actions (high frequency). This is presented simplified in Figure 2.

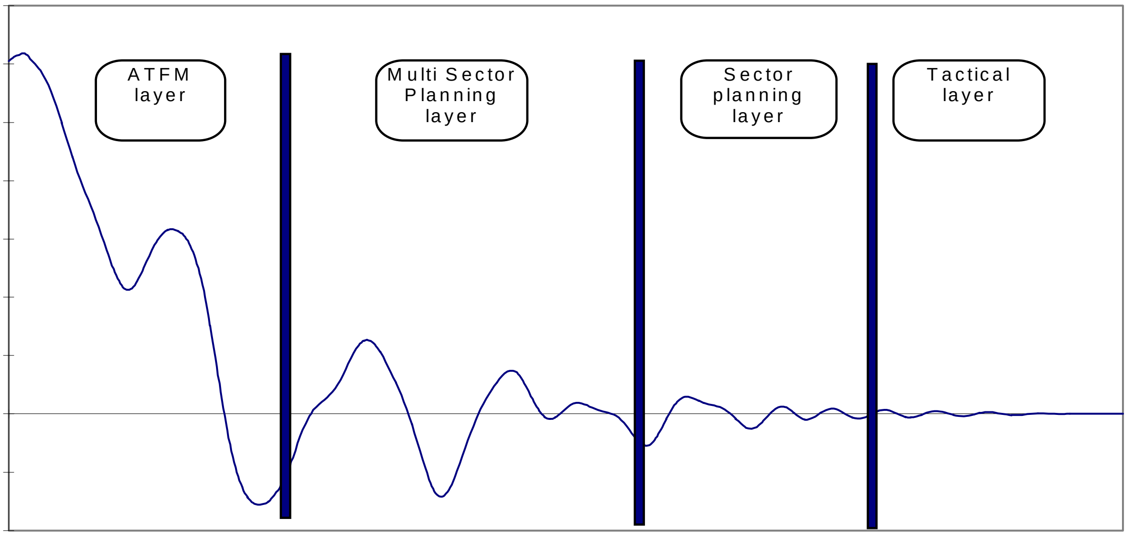

Figure 2 - Convergence in a layered ATM system

3.2 Convergence

Convergence of an ATM planning and control process can be achieved if each layer matches the capabilities of the adjacent layers by filtering out the disturbing uncertainties that subsequent layers can not handle.

Furthermore disturbances should not introduce waves with characteristics (e.g. frequency) that fall outside the scope of the management layer where they are introduced or its subsequent layers. Otherwise the effects can not be controlled completely and problems can occur.

4. Flexibility

There is a general feeling that an ATM system controlled with support of an extended planning process has a risk to become inflexible. Flow planning could restrict routing choices, departure planning could limit the freedom to decide on rescheduling during the pre-departure phase, and arrival management could restrict the freedom during the approach phase, starting already before the top-of-descent. And indeed this risk is probably true. But there is a trade-off. At one side there is the penalty of planning and achieving optimal convergence. At the other side, there is a requirement for freedom and flexibility and the risk of instability and possibly induced congestion.

Aircraft operators are considered to need flexibility to adapt their plans even while they are executing them. Again this is a result of the ever changing status of their operations. Unpredictable and unplanned events will always occur and have to be taken into account by them and by the service providers. And the operators will try to get closer to optimal performance as long as aircraft are ‘constraint’ to fly sub-optimal routes and profiles.

An important question is therefore what kind of changes to their plans do aircraft operators want to make? And in what phase of the flight planning or execution? Table 2[1] tries to give some answers to these questions.

Normally, the operator deviates from his (optimised) plan when the conditions for the execution of the plan do not match those that were used to make it, or when the execution of the plan does not go as planned. However not every planning action can be honoured by ATC. Here, the collective objective conflicts with the individual one. Modifications may be required in addition to satisfy ATC objectives, which depend on the complexity and saturation of the ATM system.

Allowing autonomous flexibility in an environment which relies on an extended planning process creates tension The feasibility of Free Flight actions depends on their scope, purpose and objectives. As will be discussed now, such actions can range from pure strategic decisions, re-planning a large part of the flight, to pure tactical decisions, solving a short-term planning or tactical conflict.

The latter one, the tactical decision, is the easiest to be embedded in an ATM planning based system, but it is also the least interesting one. The purpose of solving a short-term problem is clear, and its impact on the overall planning small, causing some changes at a tactical level at most. Its long-term impact on traffic planning may be small.

The objective of allowing tactical Free Flight decisions to be taken autonomously by the aircraft can be twofold.

In areas where the current level of ATC service provisions is insufficient or not present at all, autonomous separation assurance can be beneficial. E.g. in non-radar covered areas separation standards can be reduced if airborne assured separation is supported. This concept requires aircraft equipped with ASAS [*Airborne Separation Assurance System*], a low density traffic environment and at any time assured low density flows (no hot spots). This last requirement is difficult to assure, if there is no ground controlled flow management process preceding.

The other objective could be to reduce ATC costs in low density controlled areas. The same requirements have to be fulfilled as before. In this case it might be achievable to assure the avoidance of hot spots by providing preceding flow management services. However, it is questionable if it is cost effective to operate a distributed airborne system for assured separation, if this has to be competitive with ground assured separation. If it is really feasible to assure separation, using a distributed system, why shouldn’t it be cheaper, safer, and more consistent to collect the information, process the information and up-link the decision. Because ASAS will be a rule-based system, the decisions are not expected to be essentially different, although the scope of a ground-based centralised system can take into account more complexity and possibly a larger time frame and geographical area, than a decentralised airborne system could do [Ref. 18].

Opposite to the tactical decision, pure strategic decisions are considered as another option of Free Flight. In this case it is not so much a question of solving a tactical conflict, as well as taking a decision with the objective of adapting the overall planning of the flight. Examples of such decisions have been given in table 2.

The objective of this type of decisions is more obvious, e.g.: overall flight cost may be reduced, or the flight is planned optimal with respect to flight conditions, arrival time and the commercial aspects of operators services.

What is less obvious is how a revised planning is achieved, and how the impact

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[1] This table is based on the hypothetical situation that flights can principally follow their optimised plan and it mainly describes airline operations.

on the ATM planning in other controlled airspace is managed. The question is how to judge the proposal and how to compare it with problems on arrival and eventually en-route management. Is the pilot able to understand the impact of a delayed arrival? When is there a risk to impose required holding manoeuvres, following a change? Finally, who will accept the change and who will co-ordinate flightplan changes in Free Flight Airspace, and which controller on the ground will look after the impact of adapted planning on adjacent controlled airspace?

Item to be flexible	to -1day *strategic ATFM*	-1 day to -30 min (← pre-flight) *tactical ATFM*	-30 to -10 min. (in flight →) *multi-sector planning*	-10 min. *sector planning*	Now *Tactical control*
Departure time	• extra flights/ cancel flights	• extra flights/ cancel flights/ change aircraft or aircraft type	• compensate for delays • anticipate on ATFM planning	• compensate for ground handling variation	• pre-flight checks
Route	• avoid TRAs	• gain time • avoid busy area	• avoid busy area	• re-optimise route • replan for deviation	• select alternate destination
Cruise level/ Profile	• optimise flight	• Gain time • change of a/c	• -	• Avoid turbulence	• avoid conflict
Manoeuvres	• -	• -	• -	• -	• maintain separation • avoid weather
Speed	• compensate for predicted wind	• compensate for predicted wind	• -	• -	• compensate for unpredicted wind
Arrival time	• -	• Correct for build-up delays	• connect to other flight	• -	• -

Table 2 - Free Flight and Options for flexible planning by the Airline Operator.

5. Extended planning

Planning aims to organise activities before performing them, expecting benefits from anticipation on identified problems. The longer the planning horizon, the better the potential benefits of planning, as long as the modelling aspects of the process are well understood, and therefore as long as one can trust the planning.

As indicated before success of planning in an ATM environment is restricted by e.g.:

- unexpected events, caused by operations of the Airline Operators,
- limitations in modelling the aircraft flight performance,
- non-deterministic behaviour of weather,
- the complex interactions between all the processes.

Nevertheless, there is some definite evidence that the present-day planning horizon needs to be extended and can be extended.

Aircraft performance modelling can be improved a lot, whilst the ability of 4D monitoring and guidance will enable the aircraft to follow the predicted 4D trajectory accurately. Seconds and metres are today’s units, minutes and miles are history.

Not only the modelling can be improved also the underlying exchange of information. A planning process consists of planning activities allocated at different locations, in the air and on the ground. The quality of the planning will be improved a lot if this process will use the same model characteristics, the same information on weather conditions, and the same information on flight performance intentions by all parties. Players on the ground and in the air should be able to consider the predictions, as well as possible alternatives under exactly the same conditions.

Nevertheless, if the planning is based on the most accurate prediction, the same as used to guide a flight in 4D, even then it is unavoidable that refinement of planning is required more or less continuously. This is mainly because a rigid adherence to the initial planning may lead to inefficient flight performance under circumstances that are not 100% predictable. Furthermore, the complex interaction in the system can make even a small change at the tactical level affect the process at a higher (planning) level. This is applicable in particular to time-constraint planning, such as the planning of arrival traffic. Essential elements of the European scenarios of e.g. PHARE and EATMS are therefore based on a layered planning concept, which aims at refinement and convergence, rather then trying to find the ultimate and optimal solution for each flight at once.

The conceptual development within the PHARE programme [Ref. 6,7] has been based on an extended planning horizon. This is considered feasible because of the introduction of a process called Trajectory Negotiation, in conjunction with the introduction of a 4D FMS in the aircraft. In this way, extended planning is supported by a closed-loop flight execution process.

The principle is simple. The aircraft is considered to know best what its plan is. An advanced 4D FMS can make an accurate prediction of the actual trajectory (lateral route & vertical profile) that will be flown. So, if you can send this trajectory to the ATC system using a data-link, it can be used to know what the aircraft is intending to do. The ATC system (i.e. the controller) can then, if necessary, put some constraints on the planned trajectory to take into account the plans of other aircraft (the collective objective!). Again these constraints can be sent to the aircraft using the data-link so that the FMS can adjust the plan to take these constraints into account. The final trajectory, agreed between ATC and aircraft, will then be used by the aircraft for its guidance and by the ATC system as the actual system plan. Since the aircraft is using its prediction to feed its guidance, the ATC system can have a high confidence that its system plan for that aircraft is very accurate (of course independent conformance monitoring on the ground will be necessary, but that is another story). If either the pilot or the ATC controller has a need to modify the agreed plan, a new negotiation cycle can be initiated. This should allow sufficient flexibility for the pilot to modify his plans when necessary as well as for ATC to control traffic safely.

The problems should however not be underestimated to make this concept working in an operational sense in a fully sectored ATM organisation. Planning and negotiating trajectories takes time. In order to be efficient, negotiation should be done over longer periods of flight (up to 40 minutes). This involves usually several sectors. Balancing the workload and the responsibilities over the involved controllers is not simple. Finally, solving traffic problems is mostly related to changing more than one individual flightplan, and it is difficult to negotiate the relevant trajectories all at the same time over all relevant sectors, with all concerned aircraft.

This concept of Trajectory Negotiation is a vital improvement to keep flexibility, and to extend the horizon of decision making in an ATM environment based on a concept of extended planning. However, it is another question, and a fundamental one, how to keep the tactical process feasible, in an environment where trajectories are exchanged, and where the agreement between air and ground can be difficult to follow on the classical Plan View Display. Planning controllers in various sectors are involved actively in flight planning, with mainly a monitoring role at the tactical level. Also the pilots will become more involved in planning than today. The pilot flying will be monitoring whereas the pilot non-flying will be doing the planning. The tactical process is more and more reduced to monitoring, but it is not evident how any exceptional event is going to be handled.

6. Conclusion

Through this paper it has been tried to demonstrate the criticality of planning and control in high density traffic areas. The conditions for control on high density traffic are such that the interdependency of traffic flows is large, and that the effects of constraints imposed by arrival and departure flows are propagating through the whole ATM system.

In such a system an extended process of planning is a prerequisite to satisfy the basic requirement of assuring safe, expeditious and orderly traffic flows. Convergence by step-wise refinement is the way to maintain flexibility. This flexibility is however limited as it should fit into the process of refinement of planning. The convergence of planning is dependent on changes, that have to be within the tolerances of the related step of refinement. However, at the same time the system should be capable to accept significant, changes on the planning of any arbitrary flight at any arbitrary moment.

A well designed planning-based ATM system will be capable of providing the freedom to operators that allows it to be called a Free Flight system. Each pilot is allowed to take decisions on flight changes only being restricted in a way that, in general, the changes will follow the step-wise refinement process, and that significant changes are not destabilising the converging planning process.

Significant R&D will still be necessary to come up with a realistic operational system. Stability of a system is demonstrated by fast-time simulations with an emphasis on modelling and quantification, whereas feasibility is demonstrated by real-time simulations. The real-time demonstrations of PHARE are good examples of clarifying the feasibility of various sub-concepts like Arrival Management, Departure Management and En-route Multi-sector Planning.

7. Glossary

ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control
ATLAS	Air Traffic Land and Air Study
ATM	Air Traffic Management
COMPAS	Computer Oriented Metering Planning and Advisory System
CTAS	Centre Tracon Advisory automation programme
EASIE	Enhanced Air traffic management and mode S Implementation in Europe
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme
EATMS	European Air Traffic Management System
FAA	Federal Aviation Administration (USA)
FEATS	Future European Air traffic management systems
FMS	Flight Management System
GARTEUR	Group for Aeronautical Research and Technology in EURope
HMI	Human Machine Interface
MAESTRO	Means to Aid Expedition and Sequencing of Traffic with Research and Optimisation
PHARE	Programme for Harmonised ATM Research in Europe
TMA	Terminal Manoeuvring Area
ZOC	Zone Of Convergence

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