SHIFT THE CURRENT AIR TRAFFIC MANAGEMENT PARADIGM: FROM MEANS TO OBJECTIVES MANAGEMENT

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Abstract

As stressed by Air Traffic Management (ATM) community, current ATM system will not be able to cope with traffic increase planned over the years to come. The aim here is to propose in the frame of the Paradigm SHIFT project a new paradigm for an innovative ATM, based on a new operational concept: Contract of Objectives. This concept introduces a new way of managing ATM by objectives instead of by means. It defines an operational link between air and ground services to perform efficiency due to the increasing of the predictability of the air transport system.

The Contract of Objectives is drafted during a negotiation phase called the Operational Plan in which all actors are involved (i.e. airlines, airports, Air Navigation Service Provider (ANSP), military units, etc.). The objective assignment and negotiation can be performed through collaborative decision-making process to establish the operational agreement assuming the right balance between productivity and safety.

The Contract of Objectives is associated with one flight and is a guarantee of results offered to the airline by the air traffic system to respect punctuality. Nevertheless it contains built-in margins for flexibility and adjustment in order to manage disruptive factors. The margins are called Target Windows.

For controllers, the incorporation of the Contract of Objectives into their activities brings an additional task. It is clear that respecting the Contract of Objectives becomes a key issue in their activities but, safety remaining the controllers’ top priority.

1. Introduction

Air transport is a production system which exists only because it meets cost-benefits criteria. In this context, air navigation is a link in a chain of production which meets financial, safety and efficiency targets. Consequently, air navigation cannot shelter from the financial rules of air transport behind the safety argument alone. Being effective, as is currently the case in terms of safety, is not sufficient with regard to air transport operations. Better results in terms of cost-efficiency must be achieved. These objectives will become all the more pressing as responses are sought to the growth trend in air traffic. The performance criteria adopted for the navigation system are twofold:

- To meet the needs of the users, i.e. the airlines through the needs of the passengers.
- If this is not possible, to compromise the requirements of the users as little as possible and, in such cases, to have available the best possible prediction in relation to the changes made. This prediction is necessary to give other transport system operators enough notice to manage the resulting reorganizations to the best of their ability given their operational constraints and profitability requirements.
The mission of air navigation can therefore be summarized as follows: to organize and monitor air traffic effectively and safely in order to meet user requirements. This is the approach adopted by the Paradigm SHIFT project on the basis of the performance criteria listed above. The Paradigm SHIFT project, started at the beginning of 2004 at EUROCONTROL Experimental Centre, is one attempt to respond to this need by investigating a new control paradigm that could cope with future air traffic demand of the horizon 2020 and beyond [1].

The initial work achieved in the Paradigm SHIFT project was to identify key-features of European ATM. The second step was to propose innovative concepts for enhancing traffic efficiency by coordinating and optimizing air navigation resources. A third step will be to assess the relevance and the validity of these concepts.

2. Features of European ATM

2.1. Operating cycle of aircraft’s

Although air navigation is concerned with the flight segment of aircraft, aircraft management cannot ignore or disregard their ground segment (aircraft management by the airports). Accordingly, a flight gains operational significance only by setting up in connection the ground segments:

- The "departure" ground segment, which determines the moment when the management of the flight segment will begin.
- The "arrival" ground segment, which determines consistency and operational validity of the flight with respect to the airline and its customers.

It would be worthwhile, at this stage, to introduce the concept of rotations, which is an operational concept for the airline, insofar as it represents both an operational approach (i.e. the means of achieving planned results) and continuity between the ground and flight segments of the aircraft.

It is nevertheless entirely possible to describe an operating cycle of aircraft as a loop divided into a “ground” part and an “air” part (Fig. 1) with an interface representing the taxiing stage. For the airport, knowing the aircraft’s off-block time at the previous airport is important, yet in an air navigation context it is equally important for airlines to be able to predict the on-block time on the arrival airport. Bringing the arrival time into line with an airline's flight schedules is an aspect of the system's performance and efficiency, since ground management of hubs and aircraft rotation satisfies both the customers and the airline. Moreover, it also facilitates aircraft reception at airports of arrival and is therefore a point of entry for Airport Collaborative Decision Making issues [2].

Fig. 1. Operating cycle of an aircraft

The loop makes it clear how important it is to increase consistency between the ground and air components of the operating cycle, since the point of exit from one component is the point of entry into another.

One criterion for air traffic production is therefore adherence to aircraft arrival times at destination airports. This criterion may be added to the two existing criteria: capacity and safety (a local criterion).

ATM is therefore at the heart of the aircraft’s life cycle because:
• It is an aspect of negotiations and decision-making with airports and airlines as regards the “ground” component.
• It is a management and adjustment factor as regards taxiing.
• Lastly, it constitutes the management and regulation factor in the “air” component.

2.2. Disruptions and uncertainty
ATM is continuously subjected to disruptions and the uncertainty management is a key for the future. Disruptions can be classified into ad hoc (meteorology, sudden limitation of runway capacity, aircraft failure, etc.), constant imprecision (inaccuracy of technology), and system-wide problems generated by interfaces between the different components of the system (Air Traffic Flow Management (ATFM) vs. Air traffic Control (ATC), and ATC vs. aircraft crew).

Future air navigation system needs to meet the solution with the levels of uncertainty and the required efficiency in relation to nature of each disruptive factor. The system should not be constrained if this brings no operational benefits, otherwise it will be too rigid and therefore incapable of managing the variability inherent in the air navigation system.

2.3. Partitioned airspace
European airspace is partitioned into different ANSP. Each of these has its own route network and working methods; this limits traffic capacity and flow, in particular at the level of the interfaces between networks. An integrated and global approach to traffic management at European level appears to be the only possible means of bringing about substantial change in terms of traffic efficiency. Functional and operational continuity between ANSPs is vital if account is to be taken of the entire operating cycle of an aircraft, thereby achieving a better understanding of air traffic as a whole.

2.4. Scarce resources
Scarce resources of ATM are not the sky. Airport take-off and landing capacities constitute genuine bottlenecks, making it impossible to respond to an increase in air traffic. The largest airports are already operating at maximum capacity and only increased optimization of the take-off and landing sequences will make it possible to cope.

3. The management by objectives
A new way for enhancing traffic efficiency is to improve functional and operational continuity in aircraft management, both on the ground and in the air, with a view to meeting safety and productivity objectives. Functional continuity has an airspace dimension (heterogeneity of European airspace) and a time dimension (from planning to execution). To this end, it is proposed to bring together all air navigation components by means of a Contract of Objectives.

3.1. Why a Contract of Objectives?
The purpose of the Contract of Objectives is to build an operational link between all air navigation actors (airlines, airports, ANSP) identifying the role and the resultant redistribution of tasks for each actor, in relation to a clear, well-defined objective which is accepted by all concerned.

This objective is general, of course, and will be declined for each actor in accordance with the actor’s specific characteristics and workload. It has the merit, however, of creating a certain amount of common ground between the actors which will enable them to interact and adapt to operational circumstances and constraints without losing sight either of the global objective, which ensures productivity, or of interactions with the other actors. The challenge, then, is to define a common operational minimum among the actors which
is sufficient to strike the right balance between efficiency and safety.

Behind these recommendations one can discern the concept of the contract, which is increasingly common in the literature on the subject: one example is the four-dimensional contract suggested in the framework of the PHARE Project [3] and the ACARE recommendations [4]; another is shared vision for airports in order to predict airport departures as accurately as possible [2]. The contracts mentioned so far have a local dimension in that they involve only a limited number of actors rather than all the actors in the air navigation system.

For this reason, it is helpful to propose a global contract for the "flight" segment. This contract must facilitate functional and operational continuity between aircraft and the ground segment, since it is compatible with the objectives of airports, and also play a role in integrating the flight segment into the rest of the system, by creating bonds of reciprocal responsibility between the airlines, the aircrew and air traffic components.

3.2. The Contract of Objectives

The Contract of Objectives is associated with one flight. It defines an arrival time envelope for the aircraft (Fig.2); the envelope will be compatible with traffic prediction capacities at that moment. Then, it contains built-in margins for flexibility and adjustment in order to manage disruptive factors. These margins are compatible with those of the other components of the aeronautical system. The Contract of Objectives is therefore a flight envelope defined on the basis of:

- The aircraft's room for maneuver (commercial flight envelope);
- Predictions relating to en-route control limitations;
- The objective to be attained. The closer one comes to the final objective, the smaller the room for maneuver becomes.

The Contract of Objectives gives the controller and aircrew the means of managing the imprecision inherent in air traffic in accordance with their own objectives. The crews' objective, therefore, is to adhere to an arrival schedule; controllers, on the other hand, must ensure aircraft safety while keeping aircraft within the envelope defined in the contract, which guarantees that the contract's objective will be respected.

The Contract of Objectives is linked with the aircraft's operating cycle and complements Airport CDM mechanisms [2]. Airport Collaborative Decision Making (CDM) mechanisms predict an off-block time; this makes it possible to refine the Contract of Objectives, the objective of which is not to adhere to a take-off time but to respect an arrival slot agreed with the airline and the airport. The arrival slot takes account of the following:

- Runway constraints at airports.
- Reception constraints and airline network and hub constraints.
- En-route control constraints.

The benefits for the airline of having a Contract of Objectives are twofold:

- The navigation system must ensure that the aircraft lands at the destination airport at the scheduled time. Adhering to a flight schedule is no longer the concern only of the aircraft's crew. The control team and the aircraft's crew are able to work in synergy.
- Since it receives a guarantee relating to the aircraft's arrival time at the moment it departs, the airline can plan its resources for ground-based management of the aircraft and optimize the management of its hubs and operations. The same applies to airport resource management.
The Contracts of Objectives are drafted on the basis of criteria relating to traffic capacity, traffic fluidity and global safety. The drafting of the Contracts of Objectives does not take account of traffic safe separation. This responsibility falls to the control position, i.e. to operators associated with air navigation actors. The Contracts of Objectives create the conditions into the airspace for control positions to perform properly their task of ensuring aircraft separation.

Through the Contract of Objectives, air traffic control is given the opportunity to go further in terms of service than "capacity and safety" alone. There is a commitment that a schedule will be adhered to at the destination airport. This means that ATC is responsible for managing traffic during the flight by allocating priorities among aircraft as appropriate in order to honor Contracts of Objectives. Information of the aircraft's final intentions, therefore, makes it possible to manage its room for maneuver earlier in order to deal with disruptive factors. ATC thus plays an active part in managing the flight by proposing solutions which meet airlines' operational targets and therefore the requirements of the crews.

3.3. Target Windows

European airspace and traffic diversity conduct to share the Air Navigation Services responsibility between different ANSP. To assume responsibility there need to have a significant autonomy in term of organization [5]. To ensure a global coherence between ANSP concerned by the airside, intermediate objectives have to be negotiated from the Contract of Objectives. The target windows define milestones marking out traffic progress. These intermediate objectives assigned to ANSP have the following functions:

- They constrain traffic progress in term of boundaries.
- They create a strong link between the planning phase and ATC operations increasing robustness of the whole system. The nature of the link has to preserve ATC initiative and windows are to be calculated according to the balance between constraints, disruptions and costs.
- The collaborative planning on objectives permits to take into account technical and economical diversity of
ANSP and give guaranties. Target Windows create add-values to technical and economical organizations.

The target windows create a common language between all the operators involved, and between the planning and the operations. Target Windows are a tool that defines efficiency objectives for the operators, and provide a monitoring tool at tactical and strategic levels, enabling them to deal with disruptions as soon as possible and with a clear view of the situation. Rather than precise 4D points, they are expressed in terms of 4D intervals of adapted width. Their size and localization reflect constraints faced by downstream components, such as punctuality at destination, runway capacity, or congested en-route area. The room for adaptation left to operations ensures resilience to disruptions and puts constraints only when necessary. Operational divergence from this planning frame is still possible, and triggers a specific decision process at strategic level called renegotiation.

3.4. Implications for the operators

3.4.1. Air traffic controllers

For controllers, the incorporation of the Contract of Objectives into their activities brings an additional task. It is clear that respecting the Contract of Objectives is a key issue in their activities, but it is still secondary to safety. Safety is the controller's top priority. The addition of this new task poses the underlying question of controller workload. When traffic is heavy, will controllers be able to provide not only a safe but also a performance-related service?

At present, it is not possible to answer this question. Interactions with the operational controllers taking part in the Paradigm SHIFT project would seem to indicate that they do not rule out the possibility entirely and feel that it is deserving of study insofar as better planning of traffic should make it possible not to overload controllers. Implied in this question, in fact, are the limits of an approach which seeks to address only one organizational aspect of the problem of air navigation without taking account of the other two of the three tactical pillars: working methods and airspace.

Although the concept of the Contract of Objectives represents one avenue for developing the air navigation system, it is clearly insufficient on its own and must be envisaged within the more precise framework of a volume of airspace and a set of working methods, in order to allow an assessment of the benefits it could bring. The choice of airspace and working methods will, of course, depend on which development hypotheses are selected in relation to the nature and quantity of the traffic.

Obviously, the introduction of an additional task making it possible to provide the service on which respecting the Contract of Objectives depends will mean that operators will have to process additional information and communications. Relations with other air navigation actors, in particular with aircraft, will change, and this will require the development of tools, interfaces and appropriate working methods.

3.4.2. Aircrews

The Contract of Objectives significantly modifies the role of aircrew in the conduct of the flight. They are no longer the only persons responsible for adhering to the arrival time at the destination. They cannot, of course, re-discuss the Contract of Objectives once it has been accepted by all the partners.

As long as the flight takes place within the envelope defined in the contract, it falls to the controller to give orders to crews regarding safety and navigation. It goes without saying that under no circumstances can controllers pilot the aircraft. All orders from controllers are submitted for approval to and executed by the crew. This means that the crew has at its
disposal on board the aircraft information telling it the position of the aircraft in the contract.

4. The Operational Plan

4.1. The concept

The process by which the Contracts of Objectives of all flights are elaborated is the Operational Plan. The drafting of the Contracts of Objectives is done at strategic level between all actors involved in the air operations (airlines, airports, ATM/ATC providers) for meeting:

- The individual requirements of the flight in question.
- The global requirements of the air transport system and all its partners. The individual requirements are a subset of the general requirements.

The operational plan mechanism is both a negotiation and refinement process: refining is more efficient than redefining. This method permits to optimize co-operations and allows agreement to be found in an early state of the process. In this case, refinement appears as implicit agreements because elements are specifying more in detail and not “called in question”. This philosophy drives the whole process of the planning phase of the ATM.

For each contract, the process of drafting depends on:

- Initial request (which may be made anywhere from several months before the flight, as in the case of scheduled flights, to a few hours before, as in the case of "last-minute" flights).
- Issue of the contract, which takes place a few minutes before off-block time at the airport.

Figure 3: The Operational Plan process

The aim of the operational plan is to manage the scarce resources represented by runway capacities and ATC organization to
avoid bottlenecks. Consequently, the drafting process goals will be:

- To adjust the resources available to fit demand. This adjustment is a two-way process, i.e. ATC resources are adjusted in accordance with user demands in the full knowledge that the resources are limited and will not be able fully to satisfy demand. This also constitutes an acknowledgement that for certain areas of airspace, it may not be possible to satisfy the whole of the demand. The system will, however, be optimized in order to satisfy demand as far as possible.
- To enhance cooperation between the various actors in air navigation in order to share and work on the most precise and up-to-date information.
- To minimize and/or attenuate global problems in order to encourage adjustments and limit the drawbacks.
- To reason at each stage of the drafting process with an appropriate level of granularity (which will depend on the data precision and the time remaining for the issuing of the final contract).
- To use "real-time" information as soon as it becomes available in order to increase the precision of the planning.

This operational plan is a real negotiation, a consensual trade-off between the needs and constraints of all the actors involved, and not only the support for a data information sharing.

4.2. The drafting process

The negotiation process of operational plan is conducted by a moderator and comprises three phases, all centered on the assessment and planning of air traffic (figure 3):

- Phase 1: airport resource management.
- Phase 2: resource management (including ANSPs) and anticipation of disruption.
- Phase 3: disruption management.

4.2.1. Phase 1

Phase 1 is initiated when the airlines express the demand. It relates mainly to flight requests submitted several weeks before the flight. The purpose is therefore to identify which resources will be available at airport level by examining runway capacities, in order to bring the resources into line with airline demand on the date when the requested flights are to be performed. This is the first stage, for it involves management of the "scarcest" resource, namely runway capacities at airports.

This phase is refined by two factors:

- The operational expertise of air navigation actors who, from their wealth of experience, when faced with similar situations, will be capable of proposing by analogy a range of responses.
- Historical air traffic data, which make it possible to define the framework within which demand and resources will fluctuate. From this phase onwards, very general data relating to meteorological forecasts or the nature of the traffic are also taken into account.

At the end of Phase 1, it is possible to advance figures relating to runway capacities at airports, on the basis of which the navigation system as a whole will subsequently be adapted. Operational agreement 1 is obtained in this way. The actors during this phase are therefore the airports, the airlines and the moderator.

4.2.2. Phase 2

Phase 2 follows Phase 1 and differs from it in that a new actor intervenes in this phase, namely Air Navigation Service Providers, whether civil or military. Phase 2 is initiated on the basis of operational agreement 1. This Agreement makes it possible:

- Firstly, to provide ANSPs with a basis for their work in preparing their strategies before the subsequent
negotiation phase, which will produce operational agreement number 2 (OA2).

- Secondly, to provide support to the actors involved in Phase 1 in order to incorporate, in the form of modifications, fresh developments relating to the predicted demand and airport resources.

Once the ANSPs have worked out their strategies on the basis of operational agreement 1, a phase of negotiations between all the actors enables the production of operational agreement 2. This agreement intervenes before the end of Phase 2, since in this way it provides each of the actors with a basis on which to work at a sufficiently early stage for them to organize themselves and deploy enough resources (staff, maintenance operations, manning plan, etc.) at the appropriate level.

At this stage, however, the results of operational agreement 2 are likely to change, as the date on which the demand will appear is a long way off and numerous disruptions will still occur. Accordingly, predictions relating to disruption and developments in the demand are modified as appropriate by the actors.

This ongoing modification process makes it possible to introduce changes to the balance between demand and resources on the basis of the most recent operational developments. These iterative modifications must, however, lead to an agreement between all the partners, which intervenes at the end of Phase 2 and is known as the final operational agreement. The final operational agreement marks the end of Phase 2 of the process of drafting the "Contracts of Objectives".

In the course of Phase 2, the negotiation process has two aims to:

- Incorporate known or probable medium-term disruption (i.e. disruption known about or considered likely to occur approximately one month before the flight) as soon as possible.
- Enhance the predictions with the operational expertise of air navigation actors and historical data concerning the traffic and associated disruption.

Decisions are taken in consultation and after negotiations between the actors. The negotiations are conducted under the supervision of the moderator, which is one of the air transport system's central bodies.

During this phase, it is important to stress that the resources must match the demand. This is because it is during this phase that the role of the air navigation system changes in relation to the present model: since its function is to respond to demand, account must be taken of the fact that air navigation, via its ANSPs and management of its airspace, must attempt to respond to that demand. It is for ATC, by mobilizing and using its resources, to find solutions which best respond to demand. It is at this level that another Paradigm SHIT concepts like decentralized design will apply [5].

4.2.3. Phase 3

Phase 3 follows on chronologically from Phase 2. It is during this phase that the real traffic progress will be incorporated on the basis of the final operational agreement and that the transition will be made between a discrete planning system and a continuous system which will take account of the real traffic situation.

As soon as Phase 3 begins, certain flights covered by the final operational agreement interact directly with flights which are already in progress, and are also confronted by disruptive factors which can no longer be dealt with at a purely strategic level. This means that data relating to the flight segments of the operating cycles of aircraft covered by the final operational agreement are taken into account when planning these flights. This leads to the definition of the Contracts of Objectives, which is issued to all the actors involved in air navigation.

Phases 1 and 2 of the process of drafting the Contracts of Objectives are preventive phases, designed to forestall global questioning
of the initial planning during Phase 3. This is why the updates, adaptations and refinements introduced during Phase 3 in particular must not be regulatory actions taken by aircraft but rather actions relating to aircraft flight paths. Until the Contracts of Objectives are issued, therefore, the air traffic management structure must be central and global.

If, in the course of the flight, the ATC system cannot honor the Contract of Objectives, either on account of poor traffic planning or because of ad hoc occurrences which cannot be managed within the margins laid down in the contracts, provision must be made for airlines, ANSPs and airports to renegotiate the contract during the flight.

Conclusion

The primary aim of implementing the Contract of Objectives is to work towards real punctuality in aircraft arrivals at and departures from airports. The financial component aims not only to satisfy airline requirements but also to enable, in global terms, the most cost-effective organization possible for all the actors. It is therefore through the financial constraints of these actors, whether they be airlines, airports or navigation bodies, that the user will reap the benefits, via the fare price inclusive of tax. As this Contract of Objectives is a consensual trade-off issued from negotiation between all the actors, even if the economical models of this different actors change, this proposed concept will be still viable.

These same Contracts of Objectives also allow all traffic management operational methods, which are bound up with the specific characteristics of the various types of traffic and local areas, to become truly adaptable.

By means of the link represented by the Contract of Objectives, this functional and operational continuity makes it possible to increase the productivity of the whole system.

Now, the management by objectives is only a concept. Proof of concept requires researches in different themes concerning the operational continuity, acceptability from ground side and on board, elaboration process of operational plan and the infrastructure required to support it. The EEC – INO business area works in this way for developing collaboration with partners.

References


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