Abstract

The exploratory Supersector project falls within the scope of research based on the hypothesis that the current proliferation of controlled sectors had led to a too rigid use of airspace to face with medium- to long-term traffic growth.

Supersector suggests a shift of paradigm from sector-division to sector-regrouping, i.e. instead of subdividing sectors to accommodate traffic growth, Supersector investigates a new control organization and practices from which traffic in large volume of airspace can be managed by teams of controllers with responsibilities no more restricted to sector-planning and radar-control but span from real-time traffic flow organization to conflict solving. In this way, it is expected that Supersector can help filling the gap between long-term predictive issues of central flow management, and short-term adaptive issues of radar-control, and thus moving from the today’s non synchronous Air Traffic Management System to a synchronous one, from a sector-control working methods to a network and flow management one, from conflict-based control to a time-based control one.

A human-in-the-loop demonstration has been realised and allowed to validate the hypothesis and to identify the pros and cons of such a synchronised ATM. Time-based ATM architecture, 4D contract of service, teamwork, trunk-structured airspace design, medium-term anticipation and layer planning working methods have been explored and results will be discussed.

Introduction

Air traffic control is an open system, though many totally independent external parameters can have a great impact. This is a paradox as performance objectives consider that these parameters are comprehensively checked, monitored and verified by the system. Unfortunately, even if the complete set of parameters is known, each parameter outcome, i.e., the exact time when it interferes with the traffic and how it will interact with other parameters, is mostly unknown. To accommodate unforeseen event with respect to capacity objectives, traffic security and fluidity, a strategy for managing the unexpected components has been developed. Today, it is divided into a predictive level and a reactive level [1].

The predictive level is set to optimize the traffic management regarding air traffic control system capacities. The main actor in Europe is Eurocontrol’s Central Flow Management Unit (CFMU), which both organize flights and adjust adequate means of the control system. This mechanism is aimed at reducing traffic complexity in order to facilitate the traffic control. The reactive part is located in the sector unit at the controller level. It is mostly related to the mechanism used to manage traffic complexity induced by planning imprecision. The traffic increase has usually been associated with a growing number of sectors, controllers and the volume of the sectors has been reducing to size of diminishing returns, sometimes called capacity maxima, leading to what can be referred as the “capacity wall”. This paradigm is now reaching its limits. The major limitation of the present ATM system is the loss of effectiveness due to the weak interactivity between the two main
contributors (i.e. imprecise long term planning coupled to a very accurate local adaptation) and could explain the “capacity wall” due to the inability to manage the network and flows. Improved capacity with respect to traffic flexibility and safety require better synergy from these contributors and hence a better control on traffic complexity.

The shift of paradigm is there: it aims at creating a continuum between the predictive and reactive parts in proposing a medium-term anticipative layers which will enable the synchronisation of all the layers (predictive, anticipative, reactive) and therefore the managing of the network. This concept will synchronize ATM operations and result in efficiency gains. The challenge consists to move from the today’s asynchronous ATM to a synchronous ATM one which is expected to provide extra-capacity.

The synchronisation of ATM components required flow stretched and just-in-time delivery mechanisms performing mainly using time and processes management. It requires interactive and distributed processes which should be performed through the exploitation (controller working methods). It requires anticipations windows to manage the look-ahead flow control (flow in large volume of actions) and predefined patterns of problems of solutions (simplified route network, rerouting) which could be performed through the infrastructure. Consequently, airspace needs to fill features on the sector volume (Supersector) and route design.

In such a synchronised system and compared to the asynchronous one, it needs to move from a conflict-based control methods (detection and resolution of conflicts) to a time-based control methods (time-based traffic organisation in order to push traffic on flow with a better management of the uncertainty), to move from a sector control unit to a flow control in a volume of responsibilities approach. Majors enablers identified are layered planning and contract of services, 3D tube airspace design and management, Flight Level Allocation Scheme (FLAS) and 4D facilities. In the 2020-2040 horizon, it is envisioned that the predictive part will be not determinist, and therefore required human-centred roles to adjust the uncertainty and predictable events. To manage the predictive 4D in an anticipative/adaptive way, it is proposed to constraint the airspace with 3D constrains and working methods focusing on the time management.

In addition, the principle of controller team for managing a Supersector has been adopted because the advantage of collaborative work performance of a team is greater than the performance of its component parts since its members work in synergy. This principle led to the hypothesis that a team of controllers would be capable of managing a larger number of aircraft than an equal number of controllers working separately. This approach is totally consistent with the principle of the Supersector, which consists in grouping a number of control sectors together in a single large volume sector.

Objectives of the Demonstration

The demonstration platform was designed to allow operational role-play by controllers in order to:

- Test the consistency and effectiveness of an approach based on layering the components of the control position, and the complementarity between these components;
- Validate the potential of this type of approach to the ATM system with a view to improving traffic capacity in connection with the forecasts for 2020.
- Investigate how and to what degree safety can be built into such an approach.
- Analyse all the concepts incorporated in this new approach to ATM with a view to determining their advantages and drawbacks, and possibly to envisage different ways in which they might be used.

The Demonstration Platform

The demonstration platform comprises a control position with a team of four controllers.
The Supersector

The Supersector has the following features (Figure 1):

- The Supersector is a volume of 150 NM by 150 NM extending from the FL190 to FL 340.
- The sector is made up of an even network and an odd network. For the purposes of the demonstration, only the even network was simulated.
- The even network is composed of two trunks which cross in the middle of the sector (a west-east trunk and a south-north trunk)
- Each trunk has right and left offsets running parallel at 5 NM.
- The west-east trunks are at flight levels 220, 280, 320 and 340.
- The north-south trunks are at flight levels 200, 240, 260 and 300.
- Aircraft climb into the sector on a parallel SID to the right of the trunk. When the aircraft is at the desired flight level, it joins the trunk. The SID has an offset to the right. Aircraft have to join a trunk before the trunk intersection at the centre of the sector. Aircraft must be in stable flight in the crossing area.
- Descending aircraft are routed at the exit to the sector via a parallel STAR to the left of the trunk. Aircraft leave the trunk after the crossing area, joining the STAR at their allocated flight level. They do not start to descend until they have joined the STAR. The STAR has an offset to the left.

Figure 1. Sector Airspace and Routes

The Controller Team

The team of four controllers is responsible for the even traffic in a single Supersector. Each controller in the team has a work interface comprising (Figure 2):

- Radar screen.
- Electronic stripboard with time-based strips (called Dynastrip) [2].
- Electronic memo screen (electronic memo and Data Link).
- Audiolan interface and associated dialogue functions.

The sector’s control position is connected to two adjacent “feeder” sectors – one responsible for feeding traffic into the sector, the other for receiving traffic leaving the sector.

Figure 2. Sector Control Position and Interface
The four controllers in the team have different tasks:

- The Inbound Manager (IM) is in charge of traffic entering the sector.
- The Sector Manager (SM) is in charge of traffic changing trunks at the crossing point.
- The Conflict Manager (CM) is in charge of safety and therefore of any conflicts arising in the sector.
- The Outbound Manager (OM) is in charge of traffic leaving the sector.

The service contracts for each controller in the team are associated with three levels of responsibility: spatial responsibility relating to the characteristics of the sector, responsibility for aircraft flows and responsibility for separation standards (4 mn. for IM and OM; 3 mn. for SM, and less than 3 mn. for CM.), which taken together cover fluidity, capacity and safety. Thus it is possible to describe three functional layers: sequencing (IM, OM, and SM), separation (CM) and supervision (SM).

Aircraft passing through the sector may be the responsibility of all the controllers, but not at the same time. Each aircraft may be the responsibility of one single controller. Only the controller with responsibility for the aircraft can give it instructions, via Data Link. However, in emergencies the CM, who has radio, can at any time override the other controllers in the team.

All the controllers have an overview of the traffic in the sector, which means that they are each monitoring the work of the other controllers.

When a controller is unable to fulfil his responsibility under his service contract or when the aircraft is no longer in his area of responsibility, he transfers it to the controller in the team who can exercise the responsibilities set out in his service contract.

**The Working Methods**

On the basis of the service contracts and the tools made available, the working methods of the controllers are:

The Inbound Manager, the Sector Manager and the Outbound Manager sequence traffic in advance. The sequencing standards impose have to make it possible to apply simple solutions to resolve potential conflicts, but above all to comply as closely as possible with flight plans when integrating aircraft changing trunks or climbing. The sequencing standards adopted do not optimise traffic capacity locally but do make it possible, in a context of traffic growth, to create the margins necessary to guarantee traffic fluidity and comply with the flight plan.

The main tools for work based on anticipation are Dynastrip, Data Link and the electronic memo system. Radar is envisaged only as a secondary tool in the sequencing function. Since the controllers work to separation standards which do not jeopardise safety, they are restricted in their solutions to changing speeds or allocating aircraft to an offset, while the Sector Manager is the only controller who can change flight levels. Only the Conflict Manager works in the short term, which is why his main working tools are radar and VHF. Dynastrip, Data Link and the electronic memo system are therefore only secondary working tools. He ensures the safety of the aircraft and compliance with separation standards by changing the speed of an aircraft, allocating it to an offset, reallocating it to the main trunk or issuing a change of flight level. Like the other controllers, he cannot adjust the headings of aircraft on account of the constraints imposed by the airspace and the sector’s air routes.

**The Demonstration Protocol**

The demonstration was performed with four French operational en-route controllers over a 5-day period. The first three days were devoted to controller training and the last two days were taken up by the demonstration itself.

The demonstration took place over two days with four sessions. Each session comprised a 90 mn. air traffic scenario. The traffic scenarios were built up from actual traffic and started with a new shift. They were designed on the basis of current traffic peaks to illustrate both traffic forecasts for 2020 and traffic loads for the various controllers on the team (IM, SM, CM and OM). The four scenarios illustrated the following topics:
• Scenario 1. Overflights at 2020 levels - current climbs - current descents.
• Scenario 2. Overflights at 2020 levels - climbs at 2020 levels - current descents.
• Scenario 3. Overflights at 2020 levels - climbs at 2020 levels - descents at 2020 levels.
• Scenario 4. Overflights at 2020 levels - climbs at 2020 levels - descents at 2020 levels.

Data were elicited from observations, questionnaires and debriefings. They were mainly qualitative data and were treated by content analysis.

Results
The results are set out in two sections:
• Impressions and general feelings of the controllers regarding the form and content of the demonstration.
• Working methods and in particular the collaborative and anticipation work.

General Feelings about the Demonstration
Controllers had varied and contradictory feelings about the demonstration.

First of all they validated the analysis presented to them regarding the limitations of the current ATM system. They are aware of the lack of functional continuity between traffic planning, which they agree is far from perfect at present, and local adaptation, which is almost entirely their responsibility. They feel that any initiative to have closer integration of these two layers would be a way of improving the capacity of the ATM system, while preserving the requisite level of safety.

As regards the solutions proposed to improve the ATM system, the controllers had mixed feelings. First of all, they validated certain solutions from a theoretical point of view. They felt that any developments would have to integrate the FLAS concept more effectively in the design of airspace and the planning of flight plans. They also thought it relevant to use offsets to facilitate traffic management, since they would bring huge gains in capacity. They also agreed that it would be possible to use relatively "simple" sectors, along the lines of the sector in the demonstration, provided that the way the sectors linked across the network allowed traffic flows to be managed flexibly and weather conditions to be accommodated. The concept of "flow balancing" was seen as a major contribution to improving the synchronisation between the various layers of the system, provided that it incorporated all actors into the decision-making process and that it was based on pre-determined and jointly agreed rules. They also stressed that the airspace structure adopted would have to be such that rare emergencies, such as descending aircraft following loss of pressure, could be handled with complete safety. The use of Data Link to spread the load of communicating with aircraft more effectively between a number of different communication media, depending on the time horizons of the dialogues was an interesting avenue to explore, provided that account was taken of the specific nature of each medium and the purpose of the dialogues. As regards working methods, the controllers were aware that they were currently working “independently” using “traditional” methods and that even if improvements were possible, they would not be able to meet the capacity and safety objectives envisaged for 2020. They were aware that the working methods had to be "standardised". This meant having visible and transparent traffic management within a sector so that it could be incorporated into a quantifiable network initiative. This would require a consistent approach involving integrating aircraft entering the sector with “acceptable” traffic patterns and delivering aircraft in a way which was consistent with the capacity of the network and the airports.

On a practical level, the controllers were faced with these concepts in the course of the role-play, which highlighted how difficult it is to shift to a totally unfamiliar working environment. Thus, the criticisms made at the time of demonstrations fall into two categories:
• Those attributable to the difficulties of coping with a different environment. In this case, the controllers approached the new environment with their current logic, not the logic for which it was conceived. It is not therefore possible to
judge the relevance of the concept, since it was not applied.

- Those linked to the relevance of the proposed concepts or to imperfections in their implementation. Of course, the two categories can be blurred in cases where controllers “refuse” to use a concept they consider totally unpractical.

Thus, in the course of the demonstrations, it was interesting to note three types of reaction:

- A priori criticisms where proposals were analysed in the current context, not in a different context.
- Criticisms of concepts which were accepted in theory, but whose impact on working methods were not appreciated in advance and which therefore is at odds with current practices.
- Criticisms associated with the limitations of the concepts proposed.

**Working Methods**

It is a real challenge to ask a team of controllers to manage a single sector on the basis of collaborative work. Although the controllers had difficulty accepting this principle, a good deal of information was gathered from the demonstration, making it possible to identify the limitations and advantages of this approach.

At the demonstrations, irrespective of the traffic scenarios, controllers were rapidly confronted with three issues:

- Responsibility;
- Traffic picture;
- Trust in the other controllers.
- Anticipation

The three first issues are clearly linked, but are analysed separately here for reasons of presentation. Underlying these issues are two factors which affect how they are to be addressed: the individual culture of the controllers and the precision of the service contracts (Figure 3).

**Figure 3. The Challenge of Collaborative Work**

**Responsibility**

Responsibility is the issue most frequently raised by the controllers to reflect their discomfort with the management of aircraft. In the model proposed, responsibility is not shared exclusively on the basis of airspace (the sector) as in the current model. Functional responsibility linking the nature of the flow and spacing between aircraft is an attenuating, or even essential, factor with spatial responsibility. Shared responsibilities between the controllers based solely on the concept of space in the Supersector would have merely produced subsectors which would have recreated the current model, with its bottlenecks. However, the apportionment of responsibility as proposed creates completely new working conditions for the controllers, although it is clear that an aircraft can be the responsibility of just one controller at a time. The radar and Dynastrip interfaces and the possibility of interacting with the aircraft were designed along these lines in order to remove any ambiguity. However, within a single geographical area, aircraft flying close to each other might be the responsibility of different controllers. This means for the controller that aircraft which are not his responsibility may manoeuvre without his being able to anticipate their movements. The result is that the controller is penalised for having issued an instruction without any qualms to an aircraft under his responsibility or for guarding against the consequences of an instruction given to an aircraft by another controller responsible for that aircraft in cases where he is not sure that the controller has seen all the consequences for the aircraft for which he is not responsible. In this connection, communication between controllers in the team by electronic memo or telephone was considered to be...
too cumbersome for such adjustments, particularly as traffic loads grow. Another aspect raised by the controllers was compliance with instructions and flight plans by aircraft crews. A constant preoccupation of controllers is to check that the aircraft are respecting their flight plans or carrying out instructions issued. This time-consuming monitoring is restricted to the aircraft for which they are responsible. Since this would have to be done for aircraft for which the controller is not responsible, there would be a considerable and unpredictable increase in his work, since this would be left to his discretion. It therefore rapidly transpired that the proposed model was not clear or precise enough to answer the concerns of the controllers as regards dealing with responsibility for the aircraft. Controllers thus applied responsibility criteria which exceeded the formal framework of what was expected of them in the proposed procedures. The consequence of this was a considerable increase in individual workload, which became inappropriate in terms of the fluidity and safety of traffic where traffic volumes were high.

In the area of responsibility, the function of the Conflict Manager was considered ambiguous with respect to the other controllers. Since the CM could on his own initiative take responsibility for an aircraft over from another controller, and since he was in charge of the safety of the aircraft (separation), the CM function was rapidly perceived by the controllers in the demonstration as the most important function. The controllers therefore tended to rely on the CM, and moreover the CM tended to want to manage everything. A further consequence was that, irrespective of the traffic, there was an imbalance between the workloads of the controllers compared with what had been envisaged. The CM thus became a bottleneck and could no longer fulfil his separation task properly. The "sequencing" layers of the IM, SM and OM were not achieved because controllers retained a "conflict-based" traffic management strategy and did not really adapt to a "time-based" strategy.

In parallel with the problems associated with the CM function, the controllers raised the need for a team leader who would have final responsibility. This is an important question which must be studied with a view to finding the proper balance between the roles and functions of the various controllers within a collective. But to achieve this, it will probably be necessary to go beyond a system involving the exclusive and comprehensive responsibility of a single operator, and draw from current arrangements for control situations with complex, high-risk processes where control is provided by a collective.

The task sharing and the interfaces proposed to the controllers were deliberately designed to enable each controller to fulfil his service contract while having an overall vision of the entire Supersector and thus the tasks of the other controllers. The aim was to promote redundancy and cross-checking between the controllers in the processing of information in order to improve safety. The controllers were open to this possibility, which allowed them:

- To know what the other controllers were doing, and in particular to plan in advance for aircraft to be assigned to them.
- To be aware of the workload of the other controllers and help them or call for help in times of high workload.
- To find collective solutions for simple situations in order to optimise them where time constraints allowed, or complex situations in order to have a more strategic vision.
- To detect errors made by a controller and rectify them, and conversely to know that another controller was monitoring what they were doing.

The demonstrations validated the usefulness of cross-checking between the controllers, with the following three reservations:

- As with responsibility, the redundancy offered by the service contracts was not sufficiently precise or formalised. This meant that they were never totally sure of the redundancy, since this was left to the discretion of the other controllers and was not based on a systematic procedure which eliminated the possibility of a "hole" in the redundancy process.
- Furthermore, it became increasingly difficult to provide such redundancy.
when the workload increased, because it was not the main task of each controller.

- The above reservations suggest that the redundancy envisaged in the demonstration was too aleatory, which is acceptable with difficulty in an operational context. Future changes to service contracts must address the issue of redundancy and make it a totally effective safety tool.

As for the lessons to be drawn from the behaviour of the controllers as regards responsibility in the collective working model, the following observations might be made:

- The principle of apportioning tasks between controllers within a single team is an innovative concept which runs counter to the past history and “individualistic” culture of air traffic control.

- The responsibility of the controllers within a team of controllers can only be shared according to levels of abstraction (role and place of a leader) and functional levels (responsibility for "sequencing" cannot be covered by responsibility for "separation").

- The limits of responsibility must be clear, not only between the controllers but also in terms of the traffic situations which have to be managed. This will mean reviewing the service contracts, which must be better defined, as well as the constraints to be imposed on airspace and traffic planning to ensure that the traffic situations encountered by the controllers comply with the service contracts. The valuable experience gained with this demonstration will be useful to this process, but does not in any way set in stone the principles of the service contracts or how many controllers should be in the team. The Supersector demonstration shows how the various layers of the ATM system are interdependent and that a model which exceeds current performances can be constructed only by taking account of this interdependence.

- In the task sharing, it is important to break away from the model of a team working for the benefit of only one operator, who would rapidly become the bottleneck of the system. The tasks must be the same irrespective of the traffic situations encountered so that every operator has an essential role in the collective's operation. Each operator must have his place in the team and the performance of the team must be the sum of the performance of all the controllers. In this way, it is possible to value the work of each member of the team and foster the operators’ sense of professional achievement.

**The Level of Traffic Picture**

The considerable growth in traffic forecast between now and 2020 puts the spotlight on the question of the traffic picture of one or more controller.

A controller must have a working knowledge of all traffic information, but it is not feasible to shrink the sectors still further in order to reduce the number of aircraft in each sector. The most plausible solutions are aid systems for the detection and/or resolution of conflicts. The very first issue to be addressed, which is still to be resolved, is the role of the human being and his complementarity with the aid system [3]. It is not feasible, given the forecast traffic volumes, to introduce parallelism between the aid and the operator to optimise human performance, because that would only increase the operator's workload, especially when activity is at its most intense. The other solution is the more caricatured approach of having a "passive" operator who intervenes when the aid system issues alerts. The main problem here is when the human operator has to take over traffic management, since he will have very little time to assimilate all the relevant information.

Traffic picture is also a key question for a controller collective, because it is possible only if the various controllers in the team have different, but complementary, pictures of overall Supersector traffic.
Indeed, the current traffic picture model involves understanding "everything", i.e. "understanding everything, everywhere, all the time". Such understanding is easily explained with respect to the current control model. During the demonstration, controllers found it hard not to apply a total traffic picture for three reasons:

- The scope of the service contracts was unclear, which gave them the impression that at any time they might have to manage and interact with most of the aircraft (particularly true for the SM and the CM).
- The culture among controllers is to work individually and therefore to have a picture of everything.
- They found it difficult to trust the other controllers as soon as safety was at issue.

The consequence of maintaining a picture of "everything" is that it is difficult to achieve on account of the number of aircraft in all or part of the Supersector. Thus, during the busiest demonstration scenarios, controllers complained that they lost an overall picture, felt that they might have overlooked things or were behind in their traffic management. On the other hand, the traffic loads to which the controllers were exposed made them realise that they could not have a picture of "everything" if they continued with the current sectors and working methods.

These results reflect that fact that there will have to be changes in the concept of traffic picture at the control position given the forecast traffic between now and 2020. A single human operator will not be able to have an exhaustive and thorough picture of all traffic within the sector.

**Trust Between Controllers in the Team**

Collective work requires relations of trust between the team members. Trust is defined from an operational point of view as the time during which a third person, or even an automated system, performs a task, or part of a task for you, so that you do not have to devote any time or attention to that task. Trust can thus be total or partial. The advantage of collaborative work is that tasks can be distributed between the members of a team so that individuals are not involved in all the tasks. Collaborative work therefore depends on trust. In any collaborative working relationship, relations with others are handled on the basis of a "trust – doubt" approach. If trust is necessary for the performance of the collective, doubt is justified to detect and identify the errors inherent in any human activity. The proper balance between doubt and trust has to be found to meet the objectives of the task. If doubt takes precedence over trust, the operator increases his workload and cannot perform his own task properly when traffic volumes rise. If, on the other hand, there is too much trust, the work of others is not being monitored.

In the course of the scenarios of the Supersector demonstration, the operational controllers placed little trust in the other team members, although in the debriefings they did not question the competence and know-how of their colleagues on the demonstration. They constantly monitored the work of team members which could have an influence on their own work. The purpose of this monitoring was partly to anticipate more effectively the consequences on their own work of the work of the other controllers, but most of all it was to safeguard against errors made by the other controllers. The consequence was a major increase in the workload of each controller, contrary to what was expected.

The information gathered in the course of the demonstration indicates that there are two potential reasons for such limited trust in similarly qualified controllers:

- The first is cultural: tactical controllers have sole responsibility for aircraft and feel that they can trust only themselves in the performance of their duties. Of course, they are on occasions helped by another controller (the planning controller) whom they trust. This is not, however, a collaborative relationship as envisaged in the Supersector demonstration, and the mechanisms of trust established between the two controllers in the controller binomial are not the same as those required when working in a team. Since they are not used to establishing such relationships...
of trust, controllers had a great deal of difficulty doing so in the demonstration.

- The second reason might be related to the very nature of the working methods. With the current methods of traffic management, controllers say that their profession is an art. This is tantamount to saying that although they can describe the principles and tools of their trade, they cannot describe the exact procedures because they feel that intuition acquired with experience plays a major role in their choices and strategies. The consequence is that the art can be practised in a number of ways and that, faced with a given situation, there are a number of totally adequate solutions, depending on the criteria favoured by the operators in question. Although this approach is very satisfactory for the job satisfaction of the operators, it can be a limitation in a collaborative approach. Indeed, inconsistency from one controller to the next makes it difficult for controllers to predict the analyses and choices of other controllers. It is nevertheless important, for work where trust is required, for each controller to have a model for the behaviour of the controllers with whom he works. Only then can genuine synergy begin to take root. Knowledge of such a model is achieved through the process of familiarisation with the other controllers, as is currently the case within a controller binomial. It can also be achieved through a higher level of standardisation of situations and practices to cope with the broad range of controllers who might be encountered, in order to reduce the time needed to build trust. It is possible that the fact that the controllers involved in the demonstration had never worked with each other did hamper the process of building trust. However, it is also clear that better definition and standardisation of the procedures would have made it easier to build trust. This process of formalising procedures is very much part of the initiative to define a new ATM system and of the synchrony between its various layers.

**Anticipation**

Although for the reasons set out above the controllers preferred to apply "conflict-based" rather than “time-based” strategies for traffic management, they confirmed that the Supersector structure and the Dynastrip tool enabled them to anticipate future traffic more effectively. This advantage of the Supersector is attributable to the sectors, which are much simpler than the current sectors. The small number of routes, the fact that they are straight and that there are few convergence points owing to the use of FLAS makes it easier to have a picture of the traffic and its future developments. These simplified sectors are also a factor in helping controllers to memorise information. However, the impact of the simplification of airspace on the processing of information has to be set against the traffic load.

Anticipation had the following benefits for the controllers in their activities:

- A reduction in the number of conflicts for the Conflict Manager, who had to apply separation standards.
- Increased time margins for dealing with undetected events or events detected at a late stage.
- Compliance with the contract to manage traffic with a limited and predetermined number of solutions. Thus controllers did not need to issue aircraft instructions to aircraft, which was in any case not possible.

Overall the controllers felt that anticipating enabled them to have a better picture of the traffic and to detect situations which required their intervention earlier, either to respect the "sequencing" or to ensure "separation".

**Discussion and Conclusion**

This observation raises the question of the role of the human operator in a future ATM system. The initial hypothesis for the Supersector demonstration was to leave to the human operator
all tasks relating to traffic management (from acceptance of aircraft to their transfer to the following sector). The results of the Supersector demonstration show that this hypothesis is no longer viable when traffic is doubled, even if the airspace and route network are designed for such volumes. It is also clear that the airspace and route network hypotheses proposed in Supersector, although they have not yet been fully validated from a capacity, safety and operational point of view, have capacity properties which exceed the capacities that can be developed by human operators to manage traffic on such a network. The consequence of this observation is that it will in all likelihood not be possible to propose a future ATM system without tackling the questions of complementarity between aid systems and human operators.

To date, recourse to aids in order to improve the traffic picture and situational awareness of controllers has not been encouraging enough to envisage that they could be operational by the year 2020. Villiers [4] has set out the automation limits for air traffic control on the premise that the human operator is left in the loop. Villiers’ comments confirm one of the conclusions of the Supersector demonstration, viz. that the task sharing between the human operator and the aid system has to be organised in terms of tasks or sub-tasks, and not in terms of data processing functions. With tasks apportioned in this way, the automated system has to be fully autonomous in terms of results, and most of all in terms of responsibility and of trust. Any aid system whose performance depends on interaction with human operators obliges the latter to work in parallel with the aid system and therefore creates an additional workload which is incompatible with controller work. Such systems seek to optimise controller reasoning, but this is clearly unrealistic in a dense operational environment. The aids which seem best adapted to high traffic volumes must not interfere with the human operator, or if they do the interference must be minimal. Taking as a starting point the properties of automatons and automatisms as described by Amalberti [5] it is possible, from the observations made in the Supersector demonstration, to draw up a list of recommendations on the man-machine interactions of an aid system for a future ATM system:

- The operator should be able to initiate and stop the aid system. This means that, depending on the traffic load, the operator can decide whether or not to use an aid to regulate his own workload.
- Once the aid system has been initiated, the operator should not have to monitor or supervise its operation or its results. The aid must be completely autonomous in the performance of the task set. Thus, the performance of the aid is properly formalised and totally familiar to the operator.
- Interactions between the operator and aid system must be controlled exclusively by the operator, and overlaps between the two systems must be formalised. Such interactions are not ways of enriching the aid system but "temporal and/or geographical" spaces in which the human operator incorporates the results of the aid system’s task in his own task or takes charge of the aid system’s task. This means that the aid system has to function without input from the operator if it is to meet the programmed performance.

For the operator, delegating the task must result in a reduction in traffic load. This will free up enough resources to have a good traffic picture and take the appropriate decisions.

References


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