Sector-Less Air Traffic Management

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Abstract

The growth of air traffic raises the major concern of how to simultaneously accommodate increasing numbers of aircraft in an already saturated airspace, while maintaining safety at least at the same level, and all by improving the efficiency of Air Traffic Services at least through the reduction of incurred delays. Several attempts have been made in the past, to try resolving the problem. Several short- to long-term solutions have been initiated in the Free-Flight initiative and in the European Air Traffic Management Program (EATMP). Concepts such as User-Preferred Routes, Autonomous Aircraft Operations, Flexible-Use of Airspace, are the few examples of these attempts. However, the organisation of airspace into sectors remains a major constraint to growth in these concepts, since sector capacity is fully dependent on human capacity of solving the complexity induced by large number of aircraft in a sector.

Based on the assumptions that, in near future, modern communication technologies, together with satellite-based navigation and surveillance technologies, could allow any aircraft to be monitored and controlled independently from traditional radar-based practices, we approach a new Air Traffic Management (ATM) concept that is free from sector constraints. Our work consists in exploring the possibility of controlling and monitoring aircraft individually, regardless which sectors the aircraft is supposed to fly through.

In this paper we discuss the concept called Sector-less Air Traffic Management; its technical as well as its operational feasibility. This concept proposes a drastic change in the way we traditionally control air traffic: instead of having two controllers controlling a sector containing **n** aircraft, one controller will be responsible for a limited number of **m** aircraft, from departure to arrival terminal areas (TMA). The expected benefits are the simultaneous solution the current dead-block of capacity, safety, and efficiency with respect to air traffic growth.

Keywords: innovative ATM concept, sector-less, end-to-end control,

Introduction

Certain similarities can be found between our approach for sector-less ATM and the FREER Autonomous Aircraft Operations concept that we discussed in previous Europe-US ATM R&D Seminars [1][2]. While the FREER concept suggested changes in the cockpit environment to involve pilots in the ATM loop, this sector-less concept suggests the change in the ground environment to face the capacity, safety, and efficiency problem. Both concepts suggest the decentralisation of ATC through a delegation approach: Autonomous Aircraft explores the decentralisation from ground to air; Sector-less ATM explores the decentralisation of airspace-based, sector-control to trajectory-based, individual flight control.

The essence of the concept is that aircraft could be controlled individually. A controller shall be responsible for the safety of a limited number of flights but from departure to arrival TMA, as in some military practices. It proposes a drastic change from current ATC practices, in which aircraft are controlled by sector with two controllers responsible for all aircraft flying across a sector, to the one where a controller is responsible for a very limited number of aircraft at one time.

One obvious reason supporting the proposed concept is the difficulties in inserting additional sectors facing the growth in traffic demand. As the maximum number of aircraft in a sector is constrained by human capacity, increased traffic requires additional sectors to be inserted to accommodate additional traffic. In the current situation, many sectors are either too small to be broken down further, or will have to accept a too large number of aircraft which may lead to a degradation of safety or an increase in delay. Human capacity to handle air traffic complexity is reaching its limit [3], independent of whatever decision support tools is added in as an attempt to increase it. Sector is therefore a constraint to growth, and there is obviously the need to explore new practices that could escape from this major constraint.

Another reason supporting the concept of sector-less ATM is the introduction of modern technologies in communications, navigation and surveillance.
Nowadays, satellite-based Global Positioning System (GPS) has become a proven technology not only in ground or sea transport but also in civil air transport. As an application, today's Automatic Dependent Surveillance Broadcast (ADS-B) could provide an alternative to radar control in airspace that are not fully equipped, supporting the belief that air traffic situation could be reconstructed even with better accuracy comparing to radar control. Moreover, when networked together, ground stations could provide a global view of all air traffic from anywhere in the world. A controller could then obtain the traffic information of any traffic from anywhere she/he's sitting.

On the communication front, the advances in satellite-based mobile telecommunications and in the Internet technology could lead to the assumption that, in the *future*, a controller can dialogue with any aircraft from anywhere in the world. This dialogue controller-pilot or pilot-controller, through voice and data-link communications, has been demonstrated to be technically feasible without major difficulty regarding quality of services and security issues [4]. In other words, the *future* is not that far reaching!
Yet another reason supporting the proposed concept of sector-less ATM is the ratio of number of controllers per number of operations per year. Between the US and Europe, there's a net difference, but the mean number of operations handled by one controller per year does not exceed 650. Mathematically speaking, instead of managing a number of aircraft flying across a number of sectors, requiring the attention of a number of controllers responsible for those sectors, it is not unrealistic to assume that those same number of controllers can handle such numbers of aircraft individually from departure to arrival.
Further studies will take into account the ratio of controller per Aircraft Activity (AAI) [6]. For the moment, to facilitate exploratory studies, we assume that the optimal ratio is reachable at present. One controller is responsible of one aircraft from departure to arrival. Several advantages could be deduced:

1. Safety – the controller could be seen as the safety officer for a flight. Confidence

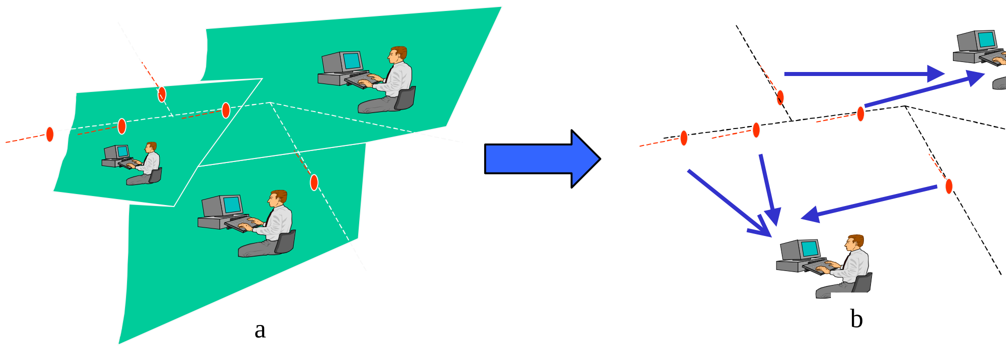

Figure 1 Basic of Sector-less concept: removing sectors and allocating aircraft to controller for individually management of flight safety. (a) Illustrates current airspace-based ATM with division of airspace into sectors (b) illustrates sector-less ATM concept from which sectors are removed, and controllers manage flight safety individually.

between pilot and controller will be increased from service provider-customer relationship to a teamwork relation. The double checking practice could only improve safety.
2. Efficiency – more time will be dedicated to enhance flight operations according to different traffic situations. Optimal solutions can be suggested to the pilot instead of just a solution.
3. Capacity – number of controllers can be increased and according to planned increased traffic regardless sector constraints.
4. End-to-end Quality of Services – current organisation of air traffic services across different control centres and countries, with their own practices and systems, represents the barriers to provide high quality end-to-end services. It is assumed that individual traffic control schemes can enhance the service delivered as well as the efficiency of the global system.
5. Continuity of Services – flight-based ATM scheme could also extend the coverage of services to areas where ground infrastructure is not or partially available, e.g. in remote areas such as some part of Africa, Asia, Pacific, etc.

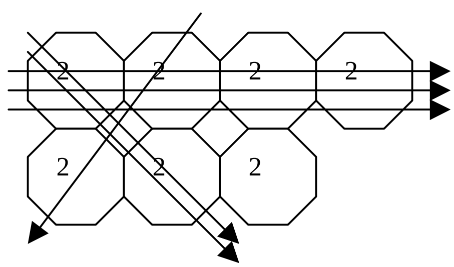

Figure 2 Currently, the mean number of controllers per sector is 2, for locally controlling a number of *n* aircraft flying across a number of *m* sectors. Individually, the ratio controller-per-aircraft decreases when the sector-less airspace increases, i.e., when *m* increases to an optimal ratio.

This practice could also help resolve the current difficulties regarding the delegation of responsibility from the ground to the air [2], which is opposed by the IFALPA ATS Committee [5]. One could imagine that the delegation of station keeping, in-trail climb and descent, etc. could be performed between controllers rather than from controller to pilots. Moreover, as the sector-less ATM concept is fully compatible with the autonomous aircraft operations, reduction of controller workload is entirely possible for long-haul flights.

Nonetheless, several questions arose at the beginning of the experimental study. From the operational viewpoint:

1. Controller Work Position induced from the change from sector-based radar to trajectory-based control?
2. Co-ordination of actions among controllers for the resolution of conflicts between 2 or more aircraft?
3. Flight-based control in terminal areas?
4. Congested airspace management? Impact on route structure, airspace design, and ATFM techniques?
5. Human resource allocation problems to cope with one-to-few control practice?
6. Transition phase?

From the technological and human factors viewpoint:

1. Which system architecture would allow a controller to access trajectory information from anywhere in the world?
2. Which techniques could support the co-ordination of conflict resolution actions without unnecessarily delaying actions from connected clusters of conflicts?
3. How to improve and/or optimise conflict detection and resolution from a single controller perspective?

From the economical and regulatory view point:

1. What economical impact?
2. Reliability?
3. National, Trans-national organisation and responsibilities?
4. Regulatory issues to maintain fair competition among stakeholders?

Approach to Problems

While investigating the different issues raised above, the global-local duality appears in most of the issues. This duality in sector-less ATM is in fact opposite to the one in current airspace-based ATM. As an example, while airspace-based ATM provides a global situation of the air to air-traffic controllers, it relies completely on local sectors. Inversely, in sector-less ATM, air-traffic

controllers manage locally individual flights but with a global view of the whole flight. In most operational, technical, and economic issues, this duality is repeated.
In our approach, this duality is used to explore the advantages and inconveniences of each suggested solution.

Controller Work Position
As mentioned earlier, Sector-less Controller Work Positions (CWP) shall be entirely redesigned to offer to controllers the technical facility for flight-management including conflict-detection and resolution, inter-controllers co-ordination, and flight monitoring. As opposed to airspace-based ATM from which the CWP is built around a radar display, and the telecommunication facility, which is local to a flight, in the sector-less concept, the CWP is built around display of global aircraft trajectories and local moving traffic situations. Our current design consists in offering to the controllers the communication facility and two visualisation interfaces: one on a local view of traffic situations, say 40 minutes, around a flight, and one on a global view of the flight with its trajectory from departure to arrival TMA. While the former is similar to radar display but just a moving radar, the trajectory display is similar to the infamous Cockpit Display of Traffic Information (CDTI) enhanced to Airborne Separation Assurance System (ASAS), sometimes called airborne Traffic Situation Display (TSD) [7].
The global-but-local moving radar allows a global perception of traffic situations as in current practice. The local-but-global trajectory editing facility allows shared situation awareness with pilot when aircraft are equipped with ASAS facility. Figure 3 illustrates the approach.

Co-ordination of Action
Collaboration, co-operation, co-action in a distributed decision-making world between controller, and eventually pilots, is of major interest. Here, the global-local duality and the contrast between airspace-based and sector-less ATM appear again.
Whilst the airspace-based co-ordination is principally sector co-ordination, and decision is local to the executive controller on a global perspective, in sector-less ATM co-ordination is *sine qua non* among controllers for a local decision that may affect the global perspective. The question that naturally comes up in the sector-less ATM concept is how controllers can co-ordinate between themselves to resolve conflicts involving *their* aircraft.

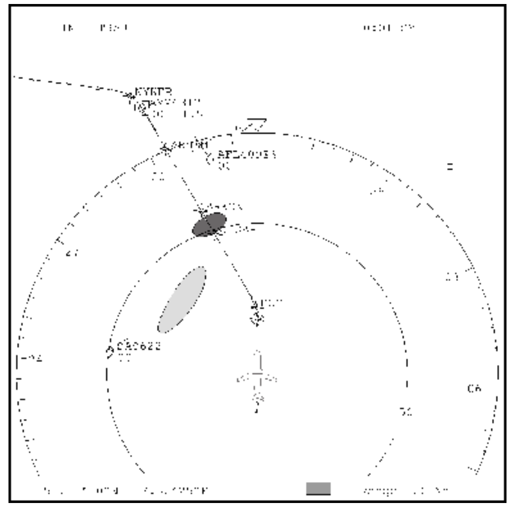

Figure 3. Similar to our approach for TSD in FREER, Flight-display for Controllers in sector-less ATM includes a representation of traffic and forbidden zones as in the aircraft navigation display. The current trajectory of own aircraft and the way-points are displayed. Each surrounding aircraft is represented. Forbidden zones are displayed. The dark grey zone is a conflict zone, while the light grey one is a no-go zone. Controller can share with pilot the same vision, and solutions to conflicts are intuitive as to avoid the no-go zones.

This question is similar to that in autonomous aircraft operations where pilots have to resolve the conflicts without ground controllers. Three schemes have been investigated in the past: (a) entirely procedural such as Extended Flight Rules (EFR) [8], (b) fully automatic co-ordination of action [9] or (c) combined procedural and automatic co-ordination [10].
Our approach consists in experimenting with the procedural for the assignment of priorities of actions in case of multiple conflicts but the scheduling of conflict resolution actions are automated. One of our exploratory studies is described in [11].
Note that in our previous study on traffic of 2015, the complexity of induced conflicts could attain 16 clusters in high-density traffic, as shown in Figure 4. Problems of co-ordination can be very complex.

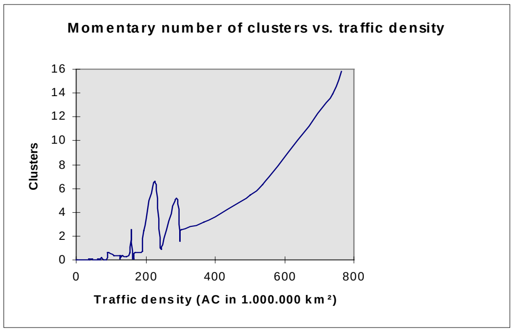

Figure 4 Momentary number of clusters vs. traffic density as simulated with European Traffic in 2015. Scenario used was direct routing with points of entry and exit plus one point representing route change, selected randomly on the flight segment.

Impacts on route structure, airspace design, and ATFM techniques

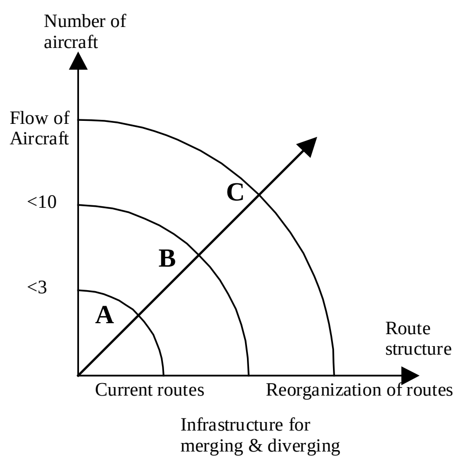

Figure 5 – Exploratory space of operational variants from (**A**) individual control to (**B**) route control, and to (**C**) controlling flow of aircraft, e.g., in station keeping, with respect to complexity of traffic and route structures. Note that in scenario (B) and (C), a controller can delegate the control of her/his aircraft to another controller after merging into, for example, a station keeping flow.

Several options have been discussed. As mentioned in the previous paragraph, free-routing operations could lead to very complex situations where co-ordination would be needed for conflicts involving up to 16 clusters of aircraft with 2015 traffic in Europe core airspace. At present, our investigations will discard the free-route scenario, but will focus on three possibilities:

(1) Unchanged current route structure;
(2) New infrastructure for merging and diverging of aircraft at major crossing of routes to adapt to the scenario following which a controller is responsible for all individual aircraft on a route; and
(3) Reorganisations of routes to offer the new possibility of handling groups of aircraft analogue to the way individual aircraft are handled.

Figure 5 illustrates the spectrum of our investigation with respect to route structures versus complexity of operational scenario.

Other Current Investigations

Terminal Area

It is recognised that the main difference between TMA and en-route operations is related to the specific knowledge and training for the management of sequences of aircraft in the TMA. In case of sector-less ATM, the issue of controlling aircraft in an unknown TMA environment is still a question, and is subjected to further investigations. At this stage of study, the question of separating departure and arrival flows, and assigning controllers specifically on each flow, is under investigation.

Logical System Architecture

The Sector-less concept implicitly places heavy reliance upon a fully integrated Wide Area ATM information system. Elements of this information system include:

- Wide Area Air Surveillance Network,
- Wide Area Flight Data Network,
- Wide Area Weather Data Network,
- Wide Area inter-CWP Communication Network,

Effort is focusing on characterising and prototyping key functional elements of this information system.

Human factors issues

Effort is currently focused on main issues that can impact the safety constructs such as:

1) Change from a controller team (radar, planner) to a single controller or a geographically distributed team:

collaboration, error/error recovery, situation awareness, and redundancy.

2) Swap from centralised control to decentralised control in different geographical location with the party-line degradation: again impacts on controller's situation awareness.
3) Control of the same aircraft during long periods: alertness, vigilance, fatigues.
4) Ability to control several aircraft flying in different geographical area and to rapidly switch context: situation awareness, memory, mental picture
5) Loss of the traffic experience: mental picture, default knowledge
6) Training, expertise/experience change.

Resource Allocation

Human resource management is an important issue as we need to move from a geographically centralised management (local sectors of control centre) to a global distributed management with an accurate and flexible allocation of local pairs of controller and aircraft.

Economical & regulatory services issues

Some economical impacts have been identified related to the human resource management (optimisation, recruitment) and scalability regards to the air transport growth. The reliability in a global system has to be compared to the difficulty encountered in the application of international laws and responsibilities in the IT world.

Conclusion

This concept proposes a drastic change to current ATC practices that one could qualify as a revolution instead of an evolution. However, it appears as one major alternative to face with continuous traffic growth without constraining the air transport industry with restrictive regulations, and all by keeping controllers as the focus of system safety.

Nonetheless, one might speculate future changing roles. Two possibilities:

- When a controller is capable of taking care of the safety of any aircraft from anywhere in the world, instead of sitting in an ACC, he could work for an airline. Though this changes, more efficiency is expected, not only for a flight but also for the global management of the airline fleet, and why not passengers comfort?
- When a controller is capable of handling flows of aircraft instead of just one or two individual ones, he could already become the real-time dynamic flow manager. Again better efficiency and capacity are more than expected.

Our route is still long. This concept can open other avenues along the axis of our investigation. This paper presents an overview of all problems and issues that we thought might be interesting for a discussion at the seminar.

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Biographies

Vu Duong is currently Head of the Innovative Research Business Area at EUROCONTROL Experimental Center. Prior to this position, he had been FREER Project Manager, ESCAPE project Manager, then Simulator Development Program Manager at the EEC. Vu holds a Master degree in Engineering, and a Ph.D. degree in Artificial Intelligence, both from Ecole Nationale des Ponts et Chaussees, France.

Gilles Gawinowski had been a software project leader at THOMSON Telecom before joining EUROCONTROL Experimental Centre in 1993 where he created the AudioLAN, IPSky, SkyTools projects and, jointly, the LOOK project. Gilles is currently Deputy Head of the Innovative Research Business Area at the EEC, and Project Leader for Sector-less ATM. He holds a Master degree in Nuclear Chemistry (Univ. Paris 7, 1989), Master in Computer Science (Univ. Paris 6, 1990), graduated in Human Factors in Aeronautics (Univ. Paris 5, 2000) and in Stress (Univ. Paris 5, 2001). He also teaches courses in Computer Science at the University Paris 6.

Jean-Pierre Nicolaon is currently Senior Operational Advisor at EUROCONTROL Experimental Centre. As a Principal Engineer of French Civil Aviation, former Controller, he had been Head of Operations at Paris ACC. He had also been the Operational Project Manager of the ARC2000 project at EEC; Chairman of the PHARE Operational Task Force in charge of the design of the Operational Concept; and Operational Advisor to the FREER-flight project. Jean-Pierre holds a private pilot license, and enjoys flying small aircraft.

Darren Smith joined EUROCONTROL Experimental Centre in 1993. Currently Technical Lead for the Sector-less ATM project, he had been the Technical Lead on the OASIS project, providing the EEC large-scale ATC Simulation platform with an advanced CORBA architecture. His notable work includes a partial implementation of the recent CORBA3 Component Model Specification. Recently, he focused his technical interests on the J2EE and J2ME technologies. Darren holds a BSc in Computer Science (Brunel University, 1991).