LIMITED DELEGATION OF SEPARATION ASSURANCE TO AIRCRAFT

The Freer-Flight Evolutionary Air-ground Cooperative ATM Concepts

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Introduction

The Operational Concept Document (OCD, [6]) of the European Air Traffic Management System (EATMS) and the ATM Strategy for 2000+ [5] proposed by EUROCONTROL envisage, within managed airspace (MAS), the possibility for controllers to delegate separation assurance tasks to pilots flying aircraft fitted with appropriate avionics. Fully autonomous aircraft operations are also envisaged for the new "Free Flight Airspace" (FFAS) proposed by the OCD. Similar applications are being considered by the Free Flight programme of the United States Federal Aviation Administration.

This paper presents work undertaken at EUROCONTROL's Experimental Centre in the area of limited delegation of separation assurance to the cockpit. It outlines the operational concept, its implications on controller working methods and the technological requirements and presents then, in more detail, two classes of applications. Finally, possible evolutions of the concept and the most relevant issues are discussed.

1 Coping with Traffic Growth

Research is currently under way in key ATM fields, such as CNS (communication, navigation, surveillance), airspace and flow management, controller working methods and support tools. Nevertheless, the forecasts for growth in traffic density in Europe and in the United States over the next fifteen years suggest that improving ground systems alone might not be sufficient to achieve the required capacity at appropriate safety levels. To achieve that, it will be necessary to develop close ground/airborne cooperation. Delegation to aircraft of some separation assurance tasks is one of the possibilities for air/ground cooperation which are now on offer.

This paper deals more specifically with the principle of delegation to aircraft of some of the separation responsibilities which are currently handled by controllers. In the same way as for visual clearances, this involves examining the possibility of giving "electronic clearances" by making use of the new CNS/ATM technologies soon to be available, in conjunction with new operational procedures.
At EUROCONTROL, the FAST (Full Aircraft Separation Transfer) study of the Freer-Flight Project (formerly FREER) looked at the "autonomous aircraft" mode in the context of free flight airspace by 2015. EFR (Extended Flight Rules) procedures have been proposed. In addition, an ASAS (Airborne Separation Assurance System) prototype providing the pilot with the necessary assistance has been developed (see e.g. [3]). A version of this prototype is even fitted on board commercial aircraft.

Various research centres in Europe (see e.g. [1, 9]), in the United States (see e.g. [7, 14]) and industry-led working groups, in particular in projects funded by the European Commission such as MAICA, NEAP, EMERTA and EMERALD [4], EUROCAE WG-51 and RTCA SC-186 [12, 13], are also investigating these areas. Under the sponsorship of EUROCONTROL/ODIAC, the terms of reference of the AIRSAW task force encompass the ASAS concepts and applications.

2 The Initial Concept

A wide range of applications has been investigated so far in the domain of air/ground cooperative ATM, ranging from short term, e.g. oceanic in-trail climb, to longer term, e.g. autonomous aircraft under free-flight operations. A promising way to classify and characterise these applications is to introduce the notion of level of delegation, which seems also particularly suitable for analysing the whole concept of delegation.

Considering the problem of separation assurance from either human or system point of view, three high level tasks can be identified:

- Identification of problems, typically detecting potential losses of separation (conflicts) between aircraft.
- Identification of a solution when a problem has been identified, typically finding the type of manoeuvre to solve a conflict, e.g. left turn.
- Implementation of the solution, e.g. selection and activation of the appropriate magnitude of heading changes, and monitoring of the implementation.

Following this high level description, three major levels of delegation can be identified in increasing order (see also [4] for a classification of applications):

- **Limited delegation.** The controller is in charge of both problem and solution identifications. Only implementation of solutions and monitoring are delegated to the pilot.
- **Extended delegation.** The controller is in charge of the identification of problems, and delegate to the pilot the identification and implementation of the solution, and the monitoring.
- **Full delegation.** Pilots are responsible for all the tasks related to separation assurance: identification of problems and solutions, implementation and monitoring.

In this context, the EACAC study (Evolutionary Air-ground Cooperative ATM Concepts, to be applied in the ECAC airspace) of the Freer-Flight Project focuses on limited delegation of separation assurance in managed airspace. EACAC targets near term applications - typically 2005 - taking place in current ATC organisations, while at the same time proposing long-term developments.

To meet this challenge, two main constraints are driving the study. The first one relates to human acceptability: respect roles and work methods of controllers and pilots, enable incremental practice and progressive confidence. Furthermore, the "acceptance dilemma" has to be overcome: no human-centred system can be used without confidence, but no confidence can be obtained without practising the system in real operations. The second constraint relates to technology: rely on minimum assumptions for CNS facilities and...
equipment modification. In addition, to enable transition phases compatibility with stepwise fleet equipment should be guaranteed.

In order to match these requirements, EACAC relies on a pragmatic and straightforward initial concept. Firstly, as for visual clearances, the concept proposed is applicable for problems involving two aircraft, and the delegation of some separation assurance tasks concerns only one aircraft. In addition, depending on the task delegated, conditions of applicability regarding each problem should be applied. This is a major issue, which is discussed for each application. Secondly, the concept relies on the following key points:

- **Limited delegation**: The task delegated to the pilot is limited to the monitoring and implementation of solutions. Thus, situation analysis, identification of problems, e.g. conflict detection, definition of solutions, and decision of delegation remain the responsibility of the controller. The delegation is proposed by the controller and requires the pilot's agreement.

- **Flexible use of delegation**: The level of tasks delegated to the pilot can range from monitoring up to implementation of a solution, leaving to the controller the ability to select the appropriate level of delegation for each problem.

3 Working Method Implications

With limited delegation, the controller retains the initiative and overall authority on situation management. The core roles and working methods of controllers and pilots remain unchanged: no dramatic change should be required, even if a new task - similar to the existing visual clearance - is introduced for the pilot. Gradual acceptance by controllers and pilots of the new separation delegation options is made possible by the concept of levels. These levels reflect increased use in practice resulting in gradual confidence building.

The flexible use of delegation also allows each individual controller to select the most appropriate level of delegation, depending on traffic conditions, airspace constraints, and the controller's confidence and level of experience. This concept also introduces the first steps towards extended levels of delegation ("up to the pilot to identify an appropriate solution"), and ultimately towards full delegation ("autonomous aircraft") (see Fig. 5).

4 Technology Considerations

No significant modification of the controller working position is initially required. However, indication of aircraft equipment on progress strips and on controller radar displays is essential for the widespread use of separation delegation. Planned trajectory intent information (such as trajectory change points) from the target aircraft is not required since identification of problems and solutions is performed by the controller. Aircraft position and velocity transmitted through ADS-B or TIS-B are sufficient for initial applications. A minimum number of cockpit display enhancements is required to support separation delegation (see Fig. 2 and 4). For the basic level, connections to the flight management system or to the autopilot are not required.

5 Applications

EACAC is intended to cover two applications:

- Sequencing, typically in TMA (Terminal Manoeuvring Area) airspace.
- Crossing and overtaking, typically in en-route airspace.

For each of these applications, three main levels of delegation have been identified: basic, intermediate, advanced. For the basic level, the delegation is extremely limited, hence
enabling early practice. Expected gains are mainly a reduction of controller workload together with the improvement of safety and flight efficiency; the higher the delegation level, the higher the expected gain.

Sequencing

For sequencing applications, three levels of delegation have been identified:

**Basic**: identification of separation. The aircraft are flying along the same trajectory, the trailing aircraft is faster than the lead one. The pilot has to report when reaching a specified separation distance. The pilot acts as an alarm clock for the controller, with the aim of reducing the controller’s monitoring work by reporting the establishment of the sequence.

**Intermediate**: station keeping. The aircraft are flying along the same trajectory, the trailing aircraft has to adjust its speed to maintain a given separation distance with respect to the lead aircraft. The controller is relieved of separation monitoring and speed adjustment clearance delivery tasks.

**Advanced**: traffic merging. Aircraft are flying along converging trajectories. The trailing aircraft has to adjust speed and, if appropriate, change heading to establish the sequence spacing prior to reaching the merging point. The controller is relieved of the succession of monitoring, and speed and heading adjustment clearance delivery tasks.

Crossing and Overtaking

For crossing and overtaking applications, three levels of separation delegation have been identified:

**Basic**: identification of the "clear of traffic". The controller ensures the separation by issuing the appropriate initial clearance. The pilot has to identify and report the "clear of traffic" event. After the pilot’s report, the controller is expected to authorise climb/descent or navigation resume. The pilot acts as an alarm clock for the controller, with the aim of reducing the controller’s monitoring work by reporting the clear of traffic.

**Intermediate**: climb/descent or navigation resume. Again, the controller ensures the separation by issuing the appropriate initial clearance. The pilot has to:

- identify and report the "clear of traffic" event, and then
- resume climb/descent or navigation.

The controller is relieved of the "clear of traffic" monitoring and resume clearance delivery tasks. In addition, the trajectories flown by the aircraft should be more efficient: shorter level-off or smaller deviations.

**Advanced**: implementation of manoeuvre. The controller identifies the conflict and selects a manoeuvre option to provide separation. The pilot has to:

- work out the appropriate manoeuvre target value, e.g. heading, and implement it;
- identify and report the "clear of traffic" event, then
- resume climb/descent or navigation. The separation delegation ends at the "clear of traffic" report.

![Figure 1: Station keeping.](image-url)
The controller is relieved of the task of implementation, including adjustment of the solution manoeuvre, continuous monitoring of the situation, and the resume clearance delivery. Again, trajectories should be even more efficient while the controller workload is significantly reduced.

6 Example Scenarios

To illustrate this, below is an example of station keeping between AFR123 and DLH456, in the initial approach phase (Fig. 1 on previous page). Both aircraft transmit and receive positions and speeds via ADS-B. In addition, the AFR is fitted with a CDTI (Cockpit Display of Traffic Information) function, showing the surrounding traffic and helping to maintain separation.

Once the problem is identified, the controller decides to propose to the AFR pilot the task of maintaining his distance behind the DLH aircraft. If the AFR pilot accepts, he enters the code of the DLH aircraft via the CDU (Control Display Unit) and sets the CDTI to Station Keeping mode. The along track distance and the projected path of the other aircraft are then displayed, enabling the pilot to adjust the aircraft speed as appropriate (Fig. 2).

Figure 2: PFD and ND in Station Keeping mode at the "Start of delegation" event (see Fig. 1). The centre of the ND, next to the DLH flight position symbol, shows the relative altitude (FL) and speed vector. The closing rate (CR, knots), and the Along Track Distance (ATD, NM) in two minute’s time are displayed at the bottom left corner. On the PFD, a "scale of separations" on the speed tape indicates the ATD for different speed values. This scale enables the pilot to identify the appropriate speed to ensure the separation from the lead aircraft. For example, reducing speed to 280 knots will increase the ATD to approximately 11Nm.

Example of station keeping dialogue (6676 is DLH456’s SSR code)

Controller: AFR123, for station keeping, select electronic traffic 6676, 10 Nm ahead
AFR Pilot: Traffic 6676 identified
Controller: AFR123, adjust speed to maintain 5Nm behind target
AFR Pilot: Maintaining 5Nm behind target
At the end of the downwind leg:
Controller: AFR123, end of delegation, contact approach 118.xx

Now let us consider a case of vertical separation assurance between AZA321 at a stable altitude and BAW654 in a descending phase (Fig. 3). The controller proposes to delegate to the BAW aircraft the task of ensuring its vertical separation above the AZA aircraft. The BAW pilot enters the AZA aircraft’s code and sets the CDTI on Vertical Separation Assurance mode. Amongst other information, the predicted separation value at the minimum separation point becomes available (Fig. 4 on next page). His task is then to adapt - as appropriate - the rate of descent to achieve the required separation, thus optimising any changes in profile. Once the two aircraft have crossed, the pilot reports the end of delegation and resumes his course.

Example of vertical crossing dialogue (5234 is AZA321’s SSR code)

Controller: BAW654, for on-board separation, select electronic traffic 5234, position target
BAW Pilot: Traffic 5234 identified, 10 o’clock, 40Nm, 100FL below
Controller: BAW654, adjust V/S to pass above target, descend FL210
BAW Pilot: Passing above target, descending FL210
When clear of traffic:
BAW Pilot: clear of traffic, descending FL210

7 An Evolving Concept

Beyond the initial concept and the examples presented, EACAC is part and parcel of an evolving framework in which three development possibilities are envisaged (Fig. 5 on next page):

- Tendency towards more autonomous operations by the additional delegation of the identification of solution types, or even of full detection and resolution with the aim of increasing safety in non-controlled areas and flight efficiency in FFAS.
- Tendency towards delegation in more complex situations, for example by delegating the implementation of solutions involving several aircraft, the objective being to increase the rate of separation delegation.
- Steering a middle course in introducing the concept, to ensure that it provides the most effective support for controllers while remaining acceptable for pilots, with a view to obtaining the optimum gain in capacity and safety.

Another method also being mooted is that of taking action upstream with the aim of breaking up complex problems into simple ones which can then be delegated. This would be done by introducing new controller working methods and more efficient airspace management.
8 Questions Raised

Separation assurance delegation, even on a limited scale, raises a number of questions which are unavoidable. Some of the most important ones are:

- Pilot-related human factor aspects and acceptability: what is the resulting workload and what level of assistance is needed (cf. [8])?
- Controller-related human factor aspects and acceptability: is, in particular, the ability to retain a "mental image" of traffic necessary (cf. [11])?
- Legal aspects: definition of legal liability?
- Safety aspects: which separation standards should apply, how should wake turbulence be dealt with?
- Technical aspects: what level of CNS data reliability is required? What are the benefits of using planned trajectory information?
- Economic aspects: how to guarantee benefits for all but some advantages also to those who are the first to fit the equipment?
Freer-Flight aims to supply answers to some of these questions. The Freer-Flight framework for the ASAS operational concept provides a link between the various ATM applications where the delegation of separation assurance responsibility may be effected at various levels.

Conclusion

An initial study (begun in early 1998) provided a statistical evaluation of the possibilities for the delegation of simple conflicts in the Maastricht upper airspace indicating significant opportunities for delegation responsibilities to pilots (cf. [2]). In addition, new display functionalities to assist separation have been developed and are to be evaluated by pilots. Lastly, a first real-time simulation involving controllers and pilots has been completed with the aim of assessing the usefulness of the system, by concentrating on the acceptability aspect and the benefits on the ground and in the air (cf. [10]). It is important to note that initially limiting delegation solely to implementation tasks should make it easier to start the testing of delegation as a new control method. The ultimate objective is to allow pilots and controllers gradually to acquire confidence in this method, and thus contribute to its operational validation.

System-wide benefits are expected in terms of safety and/or capacity. A key challenge is to ensure that each stakeholder will feel these benefits, e.g. some of the most tedious monitoring tasks of the controller will be reduced, pilot workload will be better managed due to less time-critical radiotelephony messages and better anticipation, air traffic service providers will gain airspace capacity, which for airlines will mean reduced delays, and network growths potential. However, a drastic change to the current "first come, first served" principle used both at flow management and ATC level is required. Indeed, ASAS equipment must provide immediate benefits for the airline making the investment, hence mechanisms must be devised to ensure that global system-wide benefits/gains like additional capacity or slots are first felt by the investors.

References

delegation of separation assurance to the cockpit", *SAE World Aviation Congress*, San


**Acronyms**

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<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance-Broadcast</td>
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<td>AIRSAW</td>
<td>Airborne Situational Awareness (ODIAC task force)</td>
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<td>ASAS</td>
<td>Airborne Separation Assurance System</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<td>CDTI</td>
<td>Cockpit Display of Traffic Information</td>
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<td>CDU</td>
<td>Control Display Unit</td>
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<td>CNS</td>
<td>Communication, Navigation, Surveillance</td>
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<td>EACAC</td>
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<td>EATMS</td>
<td>European Air Traffic Management System</td>
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<td>ECAC</td>
<td>European Civil Aviation Conference</td>
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<td>EFR</td>
<td>Extended Flight Rules</td>
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<td>EUROCAE</td>
<td>European Organisation for Civil Aviation Equipment</td>
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<td>FAST</td>
<td>Full Aircraft Separation Transfer</td>
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<td>FFAS</td>
<td>Free Flight Airspace</td>
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<td>FREER</td>
<td>Free Route Experimental Encounter Resolution</td>
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<td>MAS</td>
<td>Managed Airspace</td>
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<td>ND</td>
<td>Navigation Display</td>
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<td>ODIAC</td>
<td>Operational Development of Initial Air/ground data Communications</td>
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<td>PFD</td>
<td>Primary Flight Display</td>
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<tr>
<td>RTCA</td>
<td>Radio Technical Commission for Aeronautics</td>
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<td>TMA</td>
<td>Terminal Manoeuvring Area</td>
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