Limited delegation of separation assurance to the flight crew

Isabelle Grimaud, Eric Hoffman, Karim Zeghal

Following the analogy of visual clearances, the limited delegation of separation assurance to the flight crew is proposed to increase controller availability and flight crew situational awareness. A simulation involving controllers has been carried out to evaluate the potential benefits of the concept in enroute airspace and terminal area. This paper outlines the concept and presents the main results for the terminal area.

Introduction

Enhancing air traffic capacity while providing safety improvements constitutes the major challenge facing Air Traffic Management (ATM). However, the growth forecasts for air traffic in Europe and in the United States over the next fifteen years suggest that solely improving the ground component of ATM might not be sufficient to achieve the required capacity at appropriate safety levels. The development of a close co-operation between ground and airborne sides might be required to achieve this challenge. The delegation from the controller to the flight crew of some tasks related to separation assurance is proposed to increase controller availability and flight crew situational awareness. Depending on traffic conditions and airspace constraints, this increased availability is expected to provide safety improvements and to be converted into enhanced traffic capacity or flight efficiency. It takes advantage of emerging CNS/ATM technologies in pre-operational state – ADS-B or TIS-B [3] – along with additional avionics such as a Cockpit Display of Traffic Information (CDTI) [4] or an Airborne Separation Assurance System (ASAS).

The delegation of separation assurance is envisaged for en-route airspace and for terminal areas. For aircraft within an arrival stream in a terminal area, the delegation could consist in tasking the flight crew to determine and perform the necessary speed adjustments so as to maintain a given separation to the lead aircraft. A series of studies dating back to the beginning of the 80s aimed at capturing the essence of in-trail following in terminal areas, from system dynamics and pilot perspectives [1][5][6]. Later, merging operations have also been investigated [2]. These studies carried out analytical works and simulations using mathematical models, and pilot-in-the-loop experiments with cockpit simulators. The feasibility of a self-spacing technique in term of dynamics was demonstrated: the separation can be accurately maintained by pilots from cruise to final approach fix, and no instability tendency occurs in strings of aircraft. However, an increase of workload in the cockpit clearly appears thus raising the general issue of identifying the best trade-off between controller and pilot task distribution. As an initial step to address this issue, the task distribution between controllers and pilots has to be defined and the overall outcomes – benefits? – have to be evaluated.

From a controller perspective, one of the main issues arising by the delegation is the capability to maintain an adequate mental picture of the traffic with delegated aircraft. A pragmatic approach was chosen that starts from the analogy of visual clearances. More precisely, the task distribution relies on two key elements: a limited delegation in which the controller leaves no more than implementation tasks to the pilot, and a flexible use of delegation allowing to select the level of task delegated between monitoring up to implementation. This form of delegation has been defined both for sequencing applications in terminal areas, and for crossing and passing applications in en-route airspace [7]. A series of simulations has been carried out to evaluate the expected benefits with a focus on the ground side.

The present article aims at presenting the results of these simulations. It is organised as follows: the next section present a typical example. The two following sections describe the simulation characteristics and present the preliminary results on sequencing applications.

Sequencing applications

Two classes of application are considered: sequencing operations in extended terminal areas, crossing and passing applications in en-route airspace. For both classes, three levels of delegation are proposed. Typically, for the sequencing the applications and levels of delegation are described in (Table 1).

<table>
<thead>
<tr>
<th>Delegation level</th>
<th>In-trail</th>
<th>Merging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report</td>
<td>Report in-trail distance</td>
<td>Report merging distance</td>
</tr>
<tr>
<td>Maintain separation</td>
<td>Remain behind</td>
<td>Merge behind</td>
</tr>
<tr>
<td>Resume then maintain separation</td>
<td>Heading then remain behind</td>
<td>Heading then merge behind</td>
</tr>
</tbody>
</table>

Table 1. Sequencing applications.

The delegation is composed of three phases:

- Identification, in which the controller indicates the target aircraft to the pilot of the delegated aircraft.
- Instruction of delegation, in which the controller specifies the task delegated to the pilot.
- End of delegation, which marks the completion of the task delegated.

For illustration purposes, an example of the "Heading then merge behind" procedure is given (Figure 1). In the example, DLH456 is the delegated aircraft, and AFR123 is the target
a aircraft with 1234 as SSR code. The two aircraft are flying along merging trajectories in descent with compatible speeds. The controller gives a heading instruction to initiate the separation, and asks the flight crew (1) to figure out and report when the predicted separation at the merging point reaches the desired separation; (2) to resume navigation to the merging point, and (3) to adjust speed to maintain the desired separation.

Figure 1. "Heading then merge behind" scenario.

Controller: "DLH456, select target 1234"

Pilot: "Selecting target 1234, DLH456"

After pilot selection and identification on the CDTI:

Pilot: "Target 1234 identified, DLH456"

Controller: “DLH456, turn left heading 270 then behind target, merge to WPT to be 15Nm behind”

Pilot: “Turning left heading 270 then will merge to WPT to be 15Nm behind target, DLH456”

Once merging distance is 15Nm:

Pilot: “DLH456, merging distance to WPT 15Nm, merging behind target”

This delegation can be transferred to the next sector. When appropriate, the controller in charge of the delegated situation ends the delegation:

Controller: “DLH456, end delegation, reduce speed to 220 kts”

Description of the simulation

A first small scale real-time experiment took place in June '99 to collect feedback from controllers and pilots in order to assess the operational feasibility and potential interest of the concept. The overall feeling about the method was “promising with a great potential”. This method could allow an increase in controller availability. In addition, the flexible use of delegation would provide the expected flexibility to use the method under different conditions and would also enable a gradual confidence building. A second larger experiment involving six controllers from different European countries during two weeks took place in June ’00. The objective was to validate the concept in a more realistic environment and make an initial evaluation of the expected gains. For the controller, the expected gain was a workload reduction that was initially estimated through the number of instructions given. It should be noticed that the monitoring aspects also impacting on workload have not yet been evaluated. In addition, an evaluation of the impact on flight efficiency is proposed through the measurement of time, distance, and fuel consumption.

The simulation was split into two distinct sessions of one week each: one for sequencing applications and one for crossing and passing applications. Two distinct organisations were thus simulated:

- An extended Terminal Manoeuvring Area (TMA) exhibiting sequencing situations from cruise to the Initial Approach Fix (IAF).
- An en-route airspace exhibiting crossing and passing situations.

The simulated airspace was a part of Paris South East area which was thought to represent a typical high density airspace (Figure 2). Four existing sectors were selected and combined into two measured sectors. For extended TMA, the grouping – which is applied in the reality – allowed for a handling of a majority of flights from cruise to IAF by the same sector. Thus, the delegations process could be simulated and analysed during a significant period of time. In addition, direct instructions to IAF that were intensively used specifically for merging applications did not require any coordination. The traffic samples were derived from two traffic recordings. The

Figure 2. Airspace dedicated to sequencing applications. Flights landing at Charles de Gaulle (LFP) are transferred to Roissy TMA (feed sector) over SUSIN (IAF) at FL80. Flights landing at Orly (LFPO) are transferred to Orly TMA (feed sector) over MEL (IAF) at FL70.
arrival traffic was slightly increased and adjusted to create clusters of up to five aircraft. The resulting traffic was close to a real high density traffic. All the aircraft were ASAS equipped and thus capable to receive delegations.

**Preliminary results for sequencing applications**

The summary of the number of instructions is given in Figure 3. The most important result is the significant decrease in the number of instructions with delegation (28% for AO, 34% for AR). The major decrease results from the reduction of speed instructions. It should be stressed that the reduction is even more important for AR sector requiring more instructions (vectoring and speed). This reduction of instructions is thought to reflect a reduction of the task of control. As a result of the reduction of the manoeuvring actions, particularly speed and heading changes, trajectories becomes more stable. Less time-critical “guiding” to maintain separation is necessary. Concerning the number of messages exchanges (i.e. target selections included), a decrease is also visible (18% for AO and 25% for AR). An initial estimation of the efficiency variation was made through the record of time, distance and fuel consumption (Table 2). A slight decrease emerges with delegation from the three parameters. The flight efficiency is also graphically suggested on flown trajectories [7]: with delegation trajectories become straighter.

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Distance (NM)</th>
<th>Fuel (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without delegation</td>
<td>22:35</td>
<td>140</td>
</tr>
<tr>
<td>With delegation</td>
<td>21:18</td>
<td>137</td>
</tr>
</tbody>
</table>

**Table 2.** Average values of flight duration, flown distance and fuel consumption in the measured airspace.

**Conclusion**

From a qualitative perspective, the analysis of controller questionnaires indicates that the general feeling is positive: the delegation is seen as an effective and useful tool. From a quantitative perspective, the initial estimation of benefits shows that the delegation allows for a significant reduction in the number of instructions given. This is thought to reflect a possible workload reduction. However, these are only raw results. A more detailed analysis has to be performed to provide more insights on the actual impact of delegation on controller working methods (e.g. modification and/or rescheduling of tasks, monitoring). In terms of efficiency, time, distance and fuel consumption are reduced, and it appears also that trajectories become more stable. Future experiments will integrate the approach area and the cockpit perspective, and address the issue of mixed equipages and non-nominal situations.

**References**


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