This document reports on a potential set of applications of Collaborative Decision Making within Air Transport, based on an analysis of the recognised gate-to-gate phases of a flight. The applications are particularly concerned with improved information distribution and management, but also identify many potential new processes. Applications are described in terms of their context, objectives and benefits, collaborative aspects, actors, information flows, interfaces, relationship to ATM2000+ timescale, areas of cost, metrics, dependencies and further issues to be studied.
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France
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9.1 CONCLUSIONS
9.2 RECOMMENDATIONS
## GLOSSARY

This section defines the intended meaning of a number of terms used in the present report.

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborative Planning and Decision Making (CDM)</td>
<td>Refers to a set of applications aimed at improving flight operations through the increased involvement of Airlines Operations Centre (AOC) and of Airport operations in the process of Air Traffic Management (ATM). This covers applications aiming to take into account the internal priorities of the AOC or the Airport, before and during the flight, and development of Information Management systems and procedures in order to make full use of available data.</td>
</tr>
<tr>
<td>Air Traffic Management (ATM)</td>
<td>Intended here to include Airspace Management (ASM), Air Traffic Flow Management (ATFM) and Air Traffic Control (ATC).</td>
</tr>
<tr>
<td>Strategic ATFM</td>
<td>The strategic phase of the Flow Management process, taking place on a seasonal basis, from 6 months to 2 days before the day of a flight.</td>
</tr>
<tr>
<td>Pre-tactical ATFM</td>
<td>The pre-tactical phase of the Flow Management process, taking place the day before the day of operations.</td>
</tr>
<tr>
<td>Tactical ATFM</td>
<td>The tactical phase of the Flow Management process, taking place on the day of operations.</td>
</tr>
<tr>
<td>ATC Planning</td>
<td>The organising of active traffic with the objective of simplifying the tactical control task. Includes the short-term planning tasks of the Planning Controller and the medium-term planning tasks proposed in projects such as Arrivals Manager, Departures Manager and Multi-Sector Planner.</td>
</tr>
<tr>
<td>Tactical ATC</td>
<td>The tasks carried out to achieve control and monitoring of flights to ensure safety of air navigation by users. Includes radar and procedural control.</td>
</tr>
</tbody>
</table>
## ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4D</td>
<td>4 Dimensional</td>
</tr>
<tr>
<td>AA</td>
<td>Airport Authority</td>
</tr>
<tr>
<td>ACARS</td>
<td>Aircraft Communications Addressing and Reporting System</td>
</tr>
<tr>
<td>ACC</td>
<td>Area Control Centre</td>
</tr>
<tr>
<td>ADEP</td>
<td>Aerodrome of Departure</td>
</tr>
<tr>
<td>ADES</td>
<td>Aerodrome of Destination</td>
</tr>
<tr>
<td>AFTN</td>
<td>Aeronautical Fixed Telecommunication Network</td>
</tr>
<tr>
<td>AM</td>
<td>Arrivals Manager</td>
</tr>
<tr>
<td>AMAN</td>
<td>Arrivals Manager</td>
</tr>
<tr>
<td>AMC</td>
<td>Airspace Management Cell</td>
</tr>
<tr>
<td>AO</td>
<td>Aircraft Operator</td>
</tr>
<tr>
<td>AOBT</td>
<td>Actual Off-Block Time</td>
</tr>
<tr>
<td>AOC</td>
<td>Airline Operations Centre</td>
</tr>
<tr>
<td>APP</td>
<td>Approach (Control)</td>
</tr>
<tr>
<td>APT</td>
<td>Airport</td>
</tr>
<tr>
<td>Arr</td>
<td>Arrival(s)</td>
</tr>
<tr>
<td>ASD</td>
<td>Air Situation Display</td>
</tr>
<tr>
<td>ASM</td>
<td>Airspace Management</td>
</tr>
<tr>
<td>A-SMGCS</td>
<td>Advanced Surface Movements Guidance and Control System</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATCO</td>
<td>Air Traffic Control Officer</td>
</tr>
<tr>
<td>ATFM</td>
<td>Air Traffic Flow Management</td>
</tr>
<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>ATN</td>
<td>Aeronautical Telecommunication Network</td>
</tr>
<tr>
<td>ATOT</td>
<td>Actual Take-Off Time</td>
</tr>
<tr>
<td>ATS</td>
<td>Air Traffic Services</td>
</tr>
<tr>
<td>CADF</td>
<td>Central Airspace Data Function</td>
</tr>
<tr>
<td>CASA</td>
<td>Computer-Assisted Slot Allocation</td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed-Circuit Television</td>
</tr>
<tr>
<td>CDA</td>
<td>Continuous Descent Approach</td>
</tr>
<tr>
<td>CDM</td>
<td>Collaborative Decision Making</td>
</tr>
<tr>
<td>CDR</td>
<td>Conditional Route</td>
</tr>
<tr>
<td>CENA</td>
<td>Centre des Etudes de la Navigation Aérienne</td>
</tr>
<tr>
<td>CEU</td>
<td>Central Executive Unit (of CFMU)</td>
</tr>
<tr>
<td>CFMU</td>
<td>EUROCONTROL Central Flow Management Unit</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>CODA</td>
<td>Central Office of Delay Analysis</td>
</tr>
<tr>
<td>CRAM</td>
<td>Conditional Route Availability Message</td>
</tr>
<tr>
<td>CRCO</td>
<td>Central Route Charges Office</td>
</tr>
<tr>
<td>CTOT</td>
<td>Calculated Take-Off Time</td>
</tr>
<tr>
<td>Dep</td>
<td>Departure(s)</td>
</tr>
<tr>
<td>DERA</td>
<td>Defence Evaluation and Research Agency</td>
</tr>
<tr>
<td>EAMG</td>
<td>European Airspace Management Group</td>
</tr>
<tr>
<td>EATCHIP</td>
<td>European Air Traffic Control Harmonisation and Integration Programme</td>
</tr>
<tr>
<td>EATMS</td>
<td>European Air Traffic Management System</td>
</tr>
<tr>
<td>ECAC</td>
<td>European Civil Aviation Conference</td>
</tr>
<tr>
<td>EEC</td>
<td>EUROCONTROL Experimental Centre</td>
</tr>
<tr>
<td>EIBT</td>
<td>Estimated In-Block Time</td>
</tr>
<tr>
<td>ENV</td>
<td>CFMU Environment database</td>
</tr>
<tr>
<td>EOBT</td>
<td>Estimated Off-Block Time</td>
</tr>
<tr>
<td>ETA</td>
<td>Estimated Time of Arrival</td>
</tr>
<tr>
<td>ETD</td>
<td>Estimated Time of Departure</td>
</tr>
<tr>
<td>ETXS</td>
<td>Estimated Time of Exit of Stack</td>
</tr>
<tr>
<td>FAA</td>
<td>(American) Federal Aviation Authority</td>
</tr>
<tr>
<td>FDPS</td>
<td>Flight Data Processing System</td>
</tr>
<tr>
<td>FFAS</td>
<td>Free Flight Airspace</td>
</tr>
<tr>
<td>FIR</td>
<td>Flight Information Region</td>
</tr>
<tr>
<td>FMP</td>
<td>Flow Management Position</td>
</tr>
<tr>
<td>FMS</td>
<td>Flight Management System</td>
</tr>
<tr>
<td>FPL</td>
<td>Flight Plan</td>
</tr>
<tr>
<td>FSM</td>
<td>Flight Schedule Monitor</td>
</tr>
<tr>
<td>FUA</td>
<td>Flexible Use of Airspace</td>
</tr>
<tr>
<td>GA</td>
<td>General Aviation</td>
</tr>
<tr>
<td>GDP-E</td>
<td>Ground Delay Program Enhancements</td>
</tr>
<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
</tr>
<tr>
<td>IBT</td>
<td>In-Block Time</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>IFPS</td>
<td>[Integrated] Initial Flight Plan Processing System</td>
</tr>
<tr>
<td>IFTM</td>
<td>In-Flight Traffic Management</td>
</tr>
<tr>
<td>ISA</td>
<td>Innovative Slot Allocation</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organisation</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>METAR</td>
<td>Meteorological Aeronautical Radio Code</td>
</tr>
<tr>
<td>MSP</td>
<td>Multi Sector Planner</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>NAS</td>
<td>[American] National Airspace System</td>
</tr>
<tr>
<td>NLR</td>
<td>Nationaal Lucht-en-Ruimtevaartlaboratorium</td>
</tr>
<tr>
<td>OBT</td>
<td>Off-Blocks Time</td>
</tr>
<tr>
<td>OCD</td>
<td>Operational Concept Document</td>
</tr>
<tr>
<td>OMT</td>
<td>Object Modelling Technique</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer or Planning Controller</td>
</tr>
<tr>
<td>PFD</td>
<td>Planned Flight Data</td>
</tr>
<tr>
<td>PHARE</td>
<td>Programme for Harmonised ATM Research in EUROCONTROL</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RDY</td>
<td>(CFMU) Ready message</td>
</tr>
<tr>
<td>RM-ODP</td>
<td>Reference Model - Open Distributed Processing</td>
</tr>
<tr>
<td>RNAV</td>
<td>Area Navigation</td>
</tr>
<tr>
<td>RPL</td>
<td>Repetitive Flight Plan</td>
</tr>
<tr>
<td>R/T</td>
<td>Radio Telephony</td>
</tr>
<tr>
<td>RTA</td>
<td>Remote Terminal Access</td>
</tr>
<tr>
<td>RVR</td>
<td>Runway Visual Range</td>
</tr>
<tr>
<td>SAM</td>
<td>Slot Allocation Message</td>
</tr>
<tr>
<td>SAU</td>
<td>Stand Allocation Unit</td>
</tr>
<tr>
<td>SID</td>
<td>Standard Instrument Departure</td>
</tr>
<tr>
<td>SITA</td>
<td>Société Internationale de Télécommunications Aéronautiques</td>
</tr>
<tr>
<td>SP</td>
<td>Sequence Planner</td>
</tr>
<tr>
<td>SRM</td>
<td>Slot Revision Message</td>
</tr>
<tr>
<td>SRR</td>
<td>Slot Revision Request</td>
</tr>
<tr>
<td>SRS</td>
<td>Standard Routing Scheme</td>
</tr>
<tr>
<td>STAR</td>
<td>Standard [instrument] Arrival Route</td>
</tr>
<tr>
<td>SWM</td>
<td>Slot Swapping Message</td>
</tr>
<tr>
<td>SWR</td>
<td>Slot Swapping Request</td>
</tr>
<tr>
<td>TA</td>
<td>Time of Arrival</td>
</tr>
<tr>
<td>TACOT</td>
<td>TACT simulation tool</td>
</tr>
<tr>
<td>TACT</td>
<td>CFMU tactical system</td>
</tr>
<tr>
<td>TAF</td>
<td>Terminal Aerodrome Forecast</td>
</tr>
<tr>
<td>TES</td>
<td>Time of Entry in Stack</td>
</tr>
<tr>
<td>TET</td>
<td>Time of Entry in TMA</td>
</tr>
<tr>
<td>TM</td>
<td>Traffic Manager</td>
</tr>
<tr>
<td>TMA</td>
<td>Terminal Manoeuvring Area</td>
</tr>
<tr>
<td>TOM</td>
<td>Time over Outer Marker</td>
</tr>
<tr>
<td>TOS</td>
<td>Traffic Orientation Scheme</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>TOT</td>
<td>Take-Off Time</td>
</tr>
<tr>
<td>TSA</td>
<td>Temporary Segregated Area</td>
</tr>
<tr>
<td>TWR</td>
<td>[ATC] Tower</td>
</tr>
<tr>
<td>TXS</td>
<td>Time of Exit of Stack</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modelling Language</td>
</tr>
<tr>
<td>US</td>
<td>United States [of America]</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>WIR</td>
<td>What-If Rerouting</td>
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</table>
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[ATMINV] EATMS Invariant Processes Model, Ref. ECTF/DP/012, Issue 1.0; EUROCONTROL, 12/7/96.

[CDM WP] Adapted EATCHIP Work Programme document, Issue 1.0; EUROCONTROL, 03/07/98.


[PD/3-OSD] PHARE, PD/3 Operational Scenarios Document (OSD), Volume I, DOC 97-70-04, PHARE/NLR/PD3-1.1.3.2.2/OSD1;2.2, Brussels, January 1997, and, Volume II, DOC 97-70-08, PHARE/NLR.


[SMA] Private communication, N. Dubois, CENA.
1. **INTRODUCTION**

1.1 **Purpose of the Report**

This document is the final report of a project to develop and evaluate potential applications for Collaborative Planning and Decision Making, being carried out for the EUROCONTROL Directorate for EATCHIP Development within the context of the development of the European Air Traffic Management Strategy for 2000+ [ATM2000+]. The project’s objectives are described in section 2.2.

The ATM Strategy for 2000+ identifies Collaborative Planning and Decision Making as one of its key elements. The purpose of this report is to help elaborate the ideas for Collaborative Planning and Decision Making and to assist development of the concept by identifying possible specific applications of Collaborative Planning and Decision Making. It describes each and notes areas in which research and/or development may be required to progress towards their implementation. It does not attempt to prioritise or rank possible applications.

The potential applications have been developed primarily from an operational viewpoint: though technical issues have been addressed only to a limited degree.

In addition to identifying potential applications, this report gives some discussion of the general issues raised by those applications. However, it is not the purpose of this report to discuss those issues in detail.

1.2 **Acknowledgement**

A number of European organisations contributed to this project and their contributions have been used in the preparation of this report. The participating organisations were:

- EUROCONTROL Experimental Centre;
- UK DERA (Defence Evaluation and Research Agency);
- French CENA (Centre des Etudes de la Navigation Aérienne);
- Dutch NLR (Nationaal Lucht-en-Ruimtevaartlaboratorium);
- Aérospatiale.

1.3 **Organisation of the Report**

Section 2 describes the background to the project, the project’s objectives and the approach taken.

Section 3 provides an overview of the collaborative applications identified, and places them within the framework and the timescale of the ATM Strategy for 2000+ [ATM2000+].

Section 4 addresses the general issue of information management, focusing on its importance in Collaborative Planning and Decision Making.

In sections 5 to 8 the applications are described, foreseen areas of cost and benefit are identified, and required research and development activities are noted. The applications are grouped according to the core ATM process [ATM2000+] to which they relate: sections 5 to 8 cover in turn Airspace Organisation and Management, Flow and Capacity Management, En-Route and Terminal ATC, and Airport ATC.

Section 9 presents conclusions and recommendations.
2. BACKGROUND

2.1 Background to the Project

2.1.1 EATMS
The “Target Concept Statement” of the EATMS Operational Concept [EATMS OCD] is based on the idea of a Collaborative and Layered Planning System, described as:

“The exchange of current, relevant data between ATM, airports, AOCs and aircraft, to enable the different system layers to support flexible decisions where needed, taking advantage of the availability of a common information pool, enhanced equipment, computer tools and operating procedures designed to increase capacity, efficiency and safety.”

Increased involvement of the Airline Operations Centre (AOC) and the airport in the ATM process are seen as priorities. At the operational level, the requirement for increased involvement is encapsulated in the concept of Collaborative Decision Making (CDM)\(^1\), identified as one of the corner stones of the EATMS Operational Concept.

The ATM Strategy for 2000+ [ATM2000+] describes CDM as follows:

“Both the collective requirements of all airspace users and the individual aircraft operator’s preferences will be taken into account in determining solutions to events. The open systems environment and better information management will allow a permanent dialogue between the various parties (ATM, Aircraft Operators’ Operations Centres, Pilots and Airport Operations) before departure, and as the flight progresses through the ATM system. This exchange of information will enable the various organisations to continuously update each other on relevant events in real-time and provide the basis for more efficient decision making. Aircraft operators will have up-to-date and accurate information on which to base decisions about their flights, and will be able to apply factors which are not known to ATM, such as fleet management priorities, fuel consumption figures and other aircraft operating parameters, when determining solutions.”

What is now needed is to identify possible specific applications of this concept. That is the purpose of the present report.

Besides CDM, the main characteristics of the EATMS Operational Concept are [ATM2000+]:

- managing flights from gate-to-gate;
- enhancing flexibility and efficiency;
- responsive capacity management to meet demand;
- managing airspace collaboratively;
- extending the level of automation in ATC.

These characteristics are supported in the potential applications of CDM identified in this report.

\(^1\) The term “Collaborative Planning and Decision Making”, used in the specification for the present project, and the term “Collaborative Decision Making (CDM)” used in [ATM2000+] and elsewhere, refer to exactly the same concept. The latter term is used throughout the remainder of this report because it is more widely recognised and shorter.
2.1.2 Today’s ATM System
Of course, collaboration between different stakeholders in the ATM system is not a new concept—Collaborative Decision Making is a process which has always existed within the ATM world. However, it has until now been mostly an ad-hoc and human-centred process.

In today’s ATM system, Collaborative Decision Making based on information sharing is primarily identifiable as a localised process where good communications are feasible—for example at individual airports where there are close links between the ATS provider, the Airport Authority and/or the home-base airline.

2.1.3 Developments in the USA
In the USA, a number of practical applications of CDM have already been identified and are being implemented. The first set of these (previously known as the Ground Delay Programme Enhancements (GDP-E)) relate to Flow Management. The FAA CDM web site [FAA CDM] provides the following definition of CDM in the USA:

“CDM is a joint FAA/industry initiative aimed at improving Traffic Flow Management. Through increased information exchange and improved collaboration, CDM promotes the principles of collaborative problem-solving and consensus-based decision making between the various components of aviation transportation, both government and industry.”

“There are two central tenets to the CDM; better information will lead to better decision making, and tools and procedures need to be in place to enable the Air Traffic Control System Command Center and the National Airspace System (NAS) users to more easily respond to the changing conditions. The attempt to minimize the effects of the reduced airport capacity requires the up-to-date information exchange between both the airlines and FAA.”

However, CDM in the wider context is also being developed in the USA. RTCA Special Committee 169 has developed a set of CDM scenarios and defined the resulting requirements for information exchanges between ATM and AOC [RTCA].

American experience shows significant benefits from CDM to the individual participants and to the ATM system as a whole. For example, the Surface Management Advisor project at Atlanta has shown an average reduction in taxi time of 1½ minutes per aircraft, just from exchange of information between different actors at the airport [SMA]. Benefit from GDP-E elements is assessed at $2641.9 million reduction in costs to the airline industry over 20 years [FAA CDM].

The American ATM environment differs in a number of significant respects from the European one: different infrastructure, different operating procedures, and different legal and commercial environment. Hence, we need to assess the applicability of American developments in the European environment; specific developments will not necessarily be directly applicable.

This document is dedicated to identifying what might be possible in Europe. It uses experience from the US in so far as it can be applied to Europe, and also incorporates new ideas specific to the European context.

2.2 Project Objectives
The present project aims to identify possible specific applications of the concept of Collaborative Decision Making within the context of EATMS, and to develop those applications in order to assess, qualitatively, their potential costs and benefits.
The project also aims to identify areas where research and development will be needed to validate the applications and their foreseen benefits. This is intended to allow future research and development priorities to be determined. The project does not attempt to prioritise or rank the applications.

Several of the applications are not new and are included in existing programmes: their inclusion merely serves to demonstrate that CDM already exists in many places in the ATM system.

The purpose of the present project is to identify possible specific applications of CDM as a means of elaborating the concept of CDM. Thus it is not intended to define a “CDM programme”. Rather, it is proposed that the potential applications could be considered in any of the following ways (as appropriate to the application):

- by clear recognition of the application of the concept where it exists within current EUROCONTROL programmes;
- by initiation of a dedicated EUROCONTROL programme where applications are of sufficient scope and complexity to merit this, and where the development activity is definable as a separate activity independent of other programmes and with clear deliverables and timescale;
- by standalone development projects linked to activities of individual states or airports where an application is directed at localised changes in operational procedures rather than in a European-wide initiative.

2.3 Project Approach

For the purpose of this project, an application of CDM is defined to be one that aims to improving flight operations through the increased involvement of Airlines’ Operations Centres (AOC) and of Airport Operations in the process of Air Traffic Management (ATM)\(^2\). This covers applications aiming to take into account the internal priorities of the AOC or the Airport, before and during the flight, and development of Information Management systems and procedures in order to make full use of available data.

Essentially, this includes two kinds of collaboration, which can be summarised as follows:

- an area where improved exchange\(^3\) of up-to-date information, involving ATM\(^2\). Aircraft Operators (AOs) and/or Airport Authorities (AAs), will significantly help to improve the efficiency of an existing process (either overall, or for one or more actors);
- a new collaborative process in which actors exchange information on the constraints which affect their planning, and/or where decisions are delegated to the actor best-placed to take them.

The different kinds of collaboration are discussed in more detail in section 3.3.

The project employed two complementary approaches in identifying potential applications of CDM.

Firstly, the project team performed a walk-through of the EATMS “gate-to-gate” flight phases, carefully considering the interfaces between the phases, to identify areas where there is potential for collaboration. In other words to identify areas where improved information exchange between actors, or increased involvement of new actors in a decision-

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\(^2\) The term ATM is intended here to include Airspace Management (ASM), Air Traffic Flow Management (ATFM) and Air Traffic Control (ATC).

\(^3\) Information exchange could be achieved by any suitable mechanism: information broadcast as well as specific, point-to-point exchanges are included.
making process, could improve flight operations. The main characteristics of the EATMS OCD (as noted in section 2.1.1) were kept in focus throughout this walk-through.

Secondly, the conclusions of the FASTER project [FASTER] were reviewed. The FASTER project interviewed Aircraft Operators, Airport Authorities and ATM service providers (both Area and Aerodrome control) to understand what information they currently use, and how their operations could be improved by better co-operative sharing of information. This, together with other aspects of the project team's experience, ensures that the applications described here are focused on the requirements of operations staff from all parties involved in the management of air traffic.

A wide-ranging list of potential applications of CDM has been developed. The reader should appreciate, however, that this is not necessarily (and is not required to be) an exhaustive list of all the areas where CDM might be applied, since the objective of the work is to help elaborate in what form the CDM concept might be realised in Europe.

The list of potential applications shows how the concept of CDM can be applied within many of the other EATMS development programmes, and across many EATCHIP domains. The positioning of each application within EATMS is identified via the ATM core processes (Airspace Organisation and Management, Flow and Capacity Management, En-Route and Terminal ATC, and Airport ATC) [ATM2000+] and through the foreseen timeframe for the implementation of each application.

In keeping with the principle of “evolution not revolution”, the applications identified have a variety of timescales of application. They fit within a range of operational scenarios, from today’s to an advanced scenario featuring real-time information sharing, and advanced (possibly 4D) planning. The list of potential applications could therefore be used to identify a path of progressive implementation of CDM in all aspects of the ATM system.
3. OVERVIEW OF THE APPLICATIONS

3.1 Introduction
Twenty-two potential applications of Collaborative Decision Making have been identified. These were reviewed at an early stage of the project to decide which were most relevant for further development by this project. Some are the subjects of other research programmes and projects, and so to avoid duplication of effort, they have not been developed further by the present project.

All the potential applications identified are described in chapters 5 to 8. The applications that have been developed by the present project are presented in the following format:

1. General description - describes the context for the application by reference to the current ATM system and its perceived shortcomings, and outlines the proposed change;

2. Description of process - describes the process in more detail, defining which actors would be involved and their responsibilities, the information flows required, and the process steps (where appropriate);

3. ATM 2000+ timescale - notes where the application fits in with the timescale for changes proposed in the ATM Strategy for 2000+ Roadmap of Change [ATM2000+];

4. Evaluation of costs and benefits - notes foreseen areas of cost and benefit, and to which actors these would accrue, and comments on how they might be measured;

5. Dependencies - identifies pre-requisites for implementation of the application;

6. Problems and studies needed - highlights issues that would need to be considered in the further development of the application, and areas where research and development or further study is required.

Two kinds of diagrams are used to illustrate the descriptions of the potential applications:

- the first shows information flows (arrows) between actors (rectangles) and processes (ovals);
- the second illustrates the dynamic aspects of the proposed application using interaction diagrams (from the Booch/OMT/UML object modelling methodologies). Objects (or in this case actors) are represented as vertical lines, and the interactions between them are illustrated in time sequence.

In general, supporting technologies and architecture are not examined in great depth, though key issues are raised. This is because the applications are described from the operational requirement viewpoint rather than from that of technical capability.

The remainder of section 3 discusses CDM as a whole and gives an overview of the potential applications identified, placing them within various frameworks provided by the EATMS OCD and the ATM Strategy for 2000+. It also notes some of the general issues raised by the potential applications. This section is included to demonstrate the range and coherence of the potential applications, but the reader should appreciate that the main purpose of the report is the identification of specific, potential applications and not detailed discussion of the issues raised.

3.2 A Collaborative and Layered Planning System
Air Traffic Management and Control processes can be considered as a series of layers. These layers include tactical ATC and a series of planning layers that aim to arrange the
airspace and the traffic such that it is easier for tactical ATC. In time order, consider the following set of layers (or processes):

- the strategic management of airspace and traffic flows, including Airspace Management, strategic ATFM and the management of demand via Airport slots;
- pre-tactical and tactical ATFM;
- ATC planning - the organising of active traffic with the objective of simplifying the tactical control task (includes the short-term planning work of the Planning Controller and the medium-term planning tasks proposed in projects such as Arrivals Manager, Departures Manager and Multi-Sector Planner projects);
- tactical ATC - the tasks carried out to achieve control and monitoring of flights to ensure safety of air navigation by users (includes radar and procedural control).

Similar planning layers exist in parallel for each Aircraft Operator (AO) (for crew, fleet, passenger management) and each Airport Authority (AA) (for ground management: gates, aprons, stands, etc.)

These planning layers are illustrated in figure 3-1.

In the current Air Traffic Management System, traffic management and control processes tend to consider only the constraints of the ATC system, of airport capacity and of individual aircraft in an independent way. By making these processes more collaborative, we aim to enable additional constraints and priorities, those of other stakeholders, to be taken into account.
The process of tactical ATC is both time and safety critical. It can therefore be difficult to introduce new priorities and negotiation (in other words, additional complexity) into that process. However, the planning processes that aim to arrange the traffic to simplify tactical ATC are in general not time-critical, and therefore it is easier for them to consider additional constraints and priorities.

The introduction of additional priorities and constraints into planning processes can in some cases be expected to benefit the overall system (all stakeholders), for example by reducing the time taken to recover from major disruption. In other cases, individual stakeholders will benefit while the others are no worse off. Both of these represent an improvement to the overall system, and are therefore worthy aims. The details of the cost-benefit equation for each stakeholder need to be established to determine whether a given instance of collaboration is worthwhile in practice. This issue is discussed further in section 3.5.

3.3 Different Levels of Collaboration

In order for a number of different parties to plan collaboratively, they must have access to consistent sets of information, including updates. (This is not to say that all actors will necessarily have the same set of information—each actor needs only the pieces of information that are relevant to him; they will in general hold overlapping subsets of the total available information.) Making available that shared information is a necessary pre-requisite to the introduction of collaborative processes. Clearly, information management will be a key aspect of CDM; it is discussed further in section 4.

Bearing the above in mind, we envisage four possible levels of Collaboration Decision Making in any area of the Air Traffic System.

• The first level is the distribution of information that already exists somewhere in the system to additional actors. In many cases, information held by one actor would be useful to other actors in their existing planning processes. In some cases, information is already distributed, but coverage is only partial, and therefore the information that is available cannot be used effectively. In some cases, it is simply a case of a useful presentation for the information being agreed between the suppliers and the users.

• The second level can be thought of as co-operation to improve the planning estimates that are available to all—where a number of actors each hold part of the picture, they can obtain a better prediction of what the overall outcome will be by pooling their information. (For example, in predicting a flight’s take-off time considering the progress of ground preparation activities.)

• The third level is the modification of a planning process so that the current planner (usually ATM) takes into account the priorities of other actors, as communicated to him. In some cases, such collaborative planning processes could be introduced to enable the use of information that already exists in the system. In other cases, new information exchanges will be needed to support the process.

• The fourth level is the redistribution of decision making to other actors, so that each decision is taken by the actor best-placed to make that decision. This is only applicable when a decision can be separated from the overall “traffic picture”. However, where it can be incorporated, it reduces the amount of information that has to be sent to the “central” planner, and therefore improves the overall efficiency of planning operations.

Note that it will not necessarily be appropriate to identify instances of collaborative applications at all of these levels in every aspect of Air Traffic Management. Also, the proposed levels should not be viewed as an implied sequence of implementation.

The applications identified in this document fit into the above schema of planning layers and level of collaboration as shown in table 3-1 below.
Table 3-1: Potential Applications* classified by Planning Layer and Collaboration Level

<table>
<thead>
<tr>
<th>Planning layer:</th>
<th>Strategic management of airspace and traffic flows</th>
<th>Pre-tactical and Tactical Flow Management</th>
<th>ATC Planning</th>
<th>Tactical ATC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.1 CDRs in Flight Planning</td>
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<td>6.8 Airport Information for Flight Planning</td>
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<td></td>
<td>6.1 Collaborative Flow &amp; Capacity Management</td>
<td></td>
<td>7.1 Distribution of AO/Aircraft Flight Plan Information</td>
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<td></td>
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<td>7.3 Estimation of In-Block Time</td>
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<td>8.2 Estimation of Departure Time</td>
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<td>8.5 Information About Disruption</td>
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<td></td>
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<td></td>
<td>4. Information Distribution &amp; Management</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>6.2 Traffic Planning Model</td>
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<td></td>
<td>6.2 Traffic Planning Model</td>
<td>6.2 Traffic Planning Model</td>
<td>8.3 Estimation of Off-Block Time</td>
<td>7.7 Meteo Information Exchange</td>
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<td></td>
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<td>7.2 In-Flight Traffic Management</td>
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<td></td>
<td>7.4 Optimisation of Arrivals</td>
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<td></td>
<td></td>
<td></td>
<td>7.5 Integrated Arr/Dep Mgt</td>
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<td></td>
<td>8.4 Collaborative Departures Sequencing</td>
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<td></td>
<td></td>
<td></td>
<td>7.6 Autonomous Separation in Free Flight Airspace</td>
<td></td>
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<tr>
<td>Level 3 - additional actors’ priorities in planning processes</td>
<td>6.3 Co-ordination between Airport Slot and ATFM</td>
<td>6.4 Re-routing</td>
<td>6.7 Slot Shifting</td>
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<td></td>
<td>6.6 Substitution on Cancellation</td>
<td>8.6 Disruption Recovery - Departures from Nearby Airfields</td>
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<tr>
<td></td>
<td>8.1 Collaborative Stand and Gate Management</td>
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<tr>
<td>Level 4 - redistribution of decision making</td>
<td>6.1 Collaborative Flow and Capacity Management</td>
<td>6.1 Collaborative Flow and Capacity Management</td>
<td>8.1 Collaborative Stand and Gate Management</td>
<td>7.6 Autonomous Separation in Free Flight Airspace</td>
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<td></td>
<td>6.5 Slot Swapping</td>
<td>6.5 Slot Swapping</td>
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<td>6.6 Substitution on Cancellation</td>
<td>8.6 Disruption Recovery - Departures from Nearby Airfields</td>
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</tbody>
</table>

* The potential applications are described in sections 5 to 8 of this report. Note that many individual items of information are covered by the applications identified. The general issues of Information management and distribution are discussed in section 4.

### 3.4 ATM 2000+ Core Processes and Timescale

The positioning of each potential application within EATMS can be understood by viewing them within the framework of the ATM core processes, as described in [ATM2000+], and by considering the foreseen timeframe for implementation of each application. This positioning is illustrated in figure 3-2.

The hypothetical implementation timescale was developed by relating the proposed application to the operational improvements identified in ATM Strategy for 2000+ Roadmap of Change [ATM2000+]. The dates suggested are therefore based on the assumptions of [ATM2000+].
In figure 3-2 some applications overlap the boundaries between ATM core processes. This is perhaps inevitable (and desirable) for two reasons:

- we are considering a future concept where the flight is planned from gate to gate as one continuous entity;
- we are considering collaboration between actors, and the core processes of other actors do not necessarily correspond closely to those of ATM.

3.5 Costs and Benefits

To determine whether a given collaborative application is worthwhile in practice, the details of the cost-benefit equation for each stakeholder need to be established. An initial assumption would be that benefit must be greater than cost for each stakeholder. For example, if an AO has to employ more staff to cope with a new process, any financial benefit it obtains from increased operational flexibility could be negated.

Further consideration shows, however, that this initial assumption must be modified to take account of a number of issues.

Firstly, it may be sufficient that benefit is greater than cost for the air transport industry considered as a whole, although not for all individual stakeholders. For example:

- Service Providers may supply additional information or new services without direct financial return, in order to provide a better service to their users.
- Where a benefit (for example increased capacity) is necessary for the development of the industry as a whole, certain stakeholders may have to accept costs greater than their individual financial benefit.

Secondly, it may be appropriate to look at a group of applications collectively when assessing cost-benefit, rather than considering each application separately.

For example, consider the applications at the first level of collaboration (distribution of existing information): costs are incurred principally by the suppliers of the information, while benefits accrue to the new users of that information. But taken together as a group, they achieve a “critical mass” of information exchange where all participants benefit.

For a second illustration of the need to consider the cost-benefit of applications as a group, consider the case where information made available in a level 1 or 2 application is necessary to enable a level 3 or 4 collaborative process. For a given participant, the cost of providing information will outweigh the direct benefit he obtains. However, that participant may benefit significantly from introduction of the collaborative process, without incurring any further cost. Viewing the applications together, the participant’s benefit is now greater than his cost. The applications concerning Departures Management (Estimation of Take-Off Time, Estimation of Off-Blocks Time and Collaborative Departures Sequencing) provide an example of a group of applications linked in this way.

The above discussion has an implication for the practical implementation of collaborative applications. Even if, for example, airlines do not receive immediate benefit from distributing their information, they may be encouraged to provide it if a date has been set for the introduction of the a process from which they will benefit, and which relies on the new information exchanges.

3.6 Prioritisation and Equity

Several of the proposed collaborative processes concern prioritisation of some flights over others, in order to increase operational efficiency and flexibility. Prioritisation is considered an important component in maximising the efficiency of the future ATM system and enabling it to meet the future demands of airspace users.
Already in today’s ATM system, there are many cases where the sequence of traffic is adjusted from the basic first come, first served in order to increase throughput—for example in sequencing arrivals and departures to maximise runway utilisation. Some of the potential collaborative processes effectively propose an extension to this principle: new rules for ensuring equitable access to airspace, airports and ATM facilities can increase the efficiency and flexibility of the system.

The full involvement of all stakeholders will be of key importance in defining those new rules, in order to ensure that the new arrangements are acceptable to all concerned. To be feasible, a collaborative prioritisation process should not rely on “policing” from ATC or any other central agent. The process needs to be self-policing. For this, there is a strong need to have the commitment of all parties to efficient implementation of the process. That commitment can best be ensured by

- full involvement in the definition of new arrangements;
- a clear appreciation of the benefits they bring;
- transparency of process and open access to information.

Experience of the application of CDM principles to Flow Management in America [FAA CDM] has demonstrated that self-policing can work. The benefit of the new arrangements is apparent to all operators, so there is a general commitment to make the system work and ensure it is not withdrawn by the FAA. Peer pressure, backed up by transparent access to the necessary information, ensures adherence to the agreed rules.

3.7 Security

Whilst transparency of process and open access to information are essential elements of CDM, the confidentiality of certain information will need to be assured. For example:

- information may be confidential to Aircraft Operators for commercial reasons;
- information on certain categories of flight may be confidential to individual ECAC States, for reasons of national or military security.

This issue will need to be addressed in the development of information management systems and procedures.

Furthermore, the security of all the flight information that is to be shared or exchanged will need to be considered. Whilst it is essential that legitimate participants have rapid and efficient access to the required information, it will be necessary to safeguard that information from misuse by terrorists, subversive organisations and similar. Security in this context refers not only to the preventing the unauthorised reading of information, but also to preventing unauthorised or malicious writing, modification or deletion of information.

3.8 Safety

As for all developments of the ATM system, safety must be a paramount concern in the specification and implementation of applications of CDM. New developments should enhance safety, and in any case must not reduce it.

One of the central tenets of the concept of CDM is information exchange and sharing. Where information exchange and sharing takes place, the safety case must be examined thoroughly. Quality of service requirements will need to be established, and responsibility and accountability for providing the required quality of information clarified.

Some potential applications of CDM involve delegation of certain decisions from ATM authorities to new actors. Such delegation raises the issue of liability. It will be important that
responsibilities are made clear, and liability issues addressed in the development of new rules.
### Potential Applications of Collaborative Decision Making

**Figure 3-2: Potential Collaborative Applications related to ATM core processes based on the implementation timescale implied by [ATM2000+]**

<table>
<thead>
<tr>
<th>Airspace Organisation &amp; Management</th>
<th>5.1 CDRs in Flight Planning</th>
<th>6.1 Collaborative Flow &amp; Capacity Mgt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow and Capacity Management</td>
<td>6.2 Traffic Planning Model</td>
<td>6.3 Co-ord between Airport Slot and ATFM</td>
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<td>6.4 Rerouting</td>
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<td>6.5 Slot Swapping</td>
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<td>6.6 Substitution on Cancellation</td>
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<td>6.7 Slot Shifting</td>
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<td>6.8 Apt Info for Flight Planning</td>
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<tr>
<td>En-Route &amp; Terminal ATC</td>
<td>7.1 Distribution of AO/Acft Flight Plan Info</td>
<td>7.2 In-Flight Traffic Mgt</td>
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<td></td>
<td>7.3 EIBT</td>
<td>7.4 Optimisation of Arrivals</td>
</tr>
<tr>
<td></td>
<td>7.5 Integrated Arrivals and Departures Management</td>
<td>7.6 Autonomous Separation in Free Flight Airspace</td>
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<td></td>
<td>7.6 Autonomous Separation in Free Flight Airspace</td>
<td></td>
</tr>
<tr>
<td>Airport ATC</td>
<td>8.1 Collaborative Stand and Gate Mgt</td>
<td>8.2 ETD</td>
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<tr>
<td></td>
<td>8.3 EOBT</td>
<td>8.4 Collaborative Departures Sequencing</td>
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<td>8.5 Information About Disruption</td>
<td>8.6 Departures from Nearby Airfields</td>
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<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
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</thead>
</table>

EEC Note No. 19/98
4. INFORMATION MANAGEMENT

4.1 General Description

Information is the cornerstone of Collaborative Decision Making, and as such it is appropriate to consider it as a separate, but general issue, which spans the applications proposed in the following chapters.

The potential applications at collaboration level 1 and 2 (as defined in section 3.3) are essentially concerned with putting in place the procedures and infrastructure that would be required to provide additional information, filling gaps in the available information which have been identified to exist. For potential applications at collaboration level 3 and 4, the information exchange is concerned with providing the basis upon which operational procedures could be changed to help users.

This chapter addresses the general issue of information management, demonstrating that it warrants separate investigation as a means of achieving CDM.

4.2 The Information View

Other work has clearly demonstrated the need to consider information management as a separate viewpoint from which to view the ATM system [ATMINV]. Indeed, as is stated in that reference, the information management process is quite different from all the other invariant processes, which themselves concentrate on operational planning and decision making. It recommends that EATMS concept development must be focused more on development of an information-centred view of the system, as a better means of solving the system integration problem.

This should not, in itself, be surprising. It is normal in IT system development to consider a multiplicity of complementary information and process-oriented viewpoints. This is demonstrated clearly by the five viewpoints of the ISO/IEC/ITU ODP Reference Model [RM-ODP], namely Enterprise, Information, Computation, Engineering and Technology.

What is more surprising, perhaps, is that until now ATM system development "in the large" (as opposed to developments for individual systems) has focused almost exclusively on process-orientation, rather than on the information viewpoint.

4.3 Integrated Information Management

The idea of information management was described in [ATMINV], and its "positioning" relative to process-oriented view is shown in figure 4-1 [ATMINV].
The ATM virtual information pool is considered to be made up of individual information entities each of which has its own lifecycle and detail.

Numerous subject domains are identifiable, including, although not limited to [ATMINV]:

- weather information
- air navigation and hazard information
- time reference information
- geographical information
- airspace information
- air navigation system information
- traffic flow information
- mission/payload information
- flight information
- airport information
- aircraft information

Note that this includes dynamically-updated information as well as static and semi-static information.
The characteristics of the ATM virtual information pool are discussed further in [ATMINV].

4.4 Implications for CDM
As well as providing a conceptual backdrop, the information management view will encourage CDM developers to frame essential questions concerning the generation and distribution of ATM information. [FASTER] identified information items which are available from or are required by the main actors in CDM: airlines, airports and ATC. This analysis was based on operational requirements. The study demonstrated that not only is the availability of a given data item (e.g. EOBT) at a particular location (e.g. stand management unit) important, but often more important are quality of service issues. The issues to be considered include:

- accuracy and confidence - the information must be sufficiently accurate, and/or the user must be told the level of confidence in an estimate;
- stability - the information must be sufficiently stable and not subject to frequent, significant changes (but it must be updated when there are changes);
- coverage - the information must be sufficiently complete in terms of coverage;
- timeliness - the information must be available, and be current, at the time it is needed;
- consistency and coherence - the information must not conflict with other information the user receives, and must make sense to the user (for example, the user must receive a flight plan before the corresponding flight plan update); where the information is to form the basis of joint decision-making, all users must receive updates concurrently (or must synchronise their information as part of the decision-making process);
- security and confidentiality - confidential information must be protected (as discussed in section 3.7);
- availability - all legitimate users must have sufficient opportunity for access to the information;
- cost - the information must be relatively easy and low-cost to process (for example, by reliable formatting), such that it does not require a lot of manpower to use, or have high inherent communication costs.

In general terms, “better” quality information (more accurate, more timely, more secure, …) will also be more expensive. There is a trade-off between the different attributes.

Information produced for one purpose (for example airline scheduling) will have quality of service attributes that are appropriate for that purpose. They may however be quite inappropriate for another purpose (for example conflict detection). The challenge of Information Management for CDM is not simply the distribution of the relevant information, but also the management of differing requirements and capabilities in terms of quality of service.

4.5 Technology Issues
Collaborative Decision Making in today’s ATM system exists primarily as a localised process where good communications are feasible. For example, whereas users within an airport currently often have good information about the situation at that airport, other actors such as AOCs based elsewhere in practice have relatively poor information.

The increasing capability of modern communications systems means that it is now becoming possible to create more effective links over great distances. Given the relatively low cost of communications, the complexity of adding to existing infrastructure or developing
new links should not be a barrier to implementing new information distribution methods. Also, Internet and Intranet-type solutions (using web technologies) are likely to be commonplace in the future, helping to support low-cost easy access.

The required capacity, speed, reliability and availability of the links needed for each potential application will have to be assessed, along with the quality of service attributes of the information itself, to determine appropriate technologies for implementation of the applications.

As the volume of information available increases, and more regular updates are made, presentation of the information to human operators, where they are involved, becomes increasingly important. Good presentation of the information makes it much easier to understand and use, and will allow changes and anomalies to be rapidly recognised. Work on appropriate human-machine interfaces is therefore required in the development of many of the potential applications of CDM.
5. AIRSPACE ORGANISATION AND MANAGEMENT

One potential application has been identified that falls entirely within the [ATM2000+] core process of Airspace Organisation and Management: Conditional Routes in Flight Planning. This application concerns increasing the use of CDR1s and 2s in Flight Planning, thus realising more fully the capacity increase already being delivered by FUA. In addition AOs’ fuel costs will be reduced—not only because shorter routes may be flown but also because less fuel may be loaded, since the shorter routes are known at flight-planning time. Two options are suggested for handling CDRs flight planning. The first requires AOs to upgrade their flight planning systems (where necessary) to cope with Conditional Routes, and CADF to provide CRAMs in a form that can be easily integrated with, and hence processed automatically by, AOs’ flight planning systems. The second option involves introducing a mechanism for AOs to file a choice of routes, in preference order, with the FPL or RPL, and introducing software in the IFPS to select for each flight the highest-preference route available on the day.

The application is described in section 5.1.

In addition, the potential application Collaborative Flow and Capacity Management, described in section 6.1, includes some aspects of Airspace Management. However, since it describes a more dynamic and tactical process, it is included under the Flow and Capacity Management core process in section 6, rather than in the present section.

5.1 Conditional Routes In Flight Planning

5.1.1 General Description

5.1.1.1 Context

The Flexible Use of Airspace (FUA)\(^4\) initiative has begun to succeed in delivering increased ATC capacity and more flexibility for Airlines in the routing of flights. The organisational infrastructure for civil/military co-ordination, Airspace Management Cells (AMCs), are in place and operating in many states.

FUA is achieved through the use of Temporary Segregated Areas (TSAs) and Conditional Routes (CDRs). There are three categories of CDR:

- CDR1s can always be flight-planned for use during the published hours (as defined in the strategic phase); they are open by default but the AMC may decide during the pre-tactical phase to close them.
- CDR2s can only be flight-planned for use during the published hours if they have been made available during the pre-tactical phase; they are closed by default.
- CDR3s can never be flight-planned; they can only be used on ATC instructions.

Airlines (and CFMU) are informed of the availability of CDR1s and 2s by a Conditional Route Availability Message (CRAM). The Central Airspace Data Function (CADF, part of CFMU) receives notification from AMCs each day and distributes a CRAM defining CDR availability for the following day.

Although they all receive the CRAM, in practice few AOs regularly flight-plan CDR1s or CDR2s. Many flight planning systems use a pre-defined catalogue of preferred routes between each city pair served, and are not capable of handling conditional routes. It is too

\(^4\) The FUA concept is described fully in [AMH].
Potential Applications of Collaborative Decision Making

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It is important to note that a more-efficient route must be flight-plannable for the AO to obtain full benefit from it—an efficient route available at flight-planning time can reduce the fuel load that has to be carried, whereas a route that is only available in-flight reduces only the amount of fuel burnt (or the flight timing). In the latter case unnecessary fuel is carried on the flight, giving a less efficient operation than in the former case.

5.1.1.2 Objectives and Benefits
An application of CDM that could be implemented in the short term would aim to increase the use of CDRs by improving mechanisms for AOs’ use of CDRs in Flight Planning.

Two options are suggested for how this might be achieved. The first involves enabling CRAMs to be processed automatically by AOs’ flight planning systems, so that when a flight is planned, the best route available on the day is selected. In many cases, this would require the AO to upgrade its flight planning system to cope with Conditional Routes, as well as CADF to provide the CRAM in a form that could be easily integrated with the flight planning systems.

The second option involves introducing a mechanism for AOs to file a choice of routes, in preference order, and software in the IFPS to select for each flight the highest-preference route available on the day.

Increased use of CDRs would benefit AOs—an AO flying a given schedule can expect reduced fuel costs through more efficient routing. All parties should benefit from realising in full the capacity increase beginning to be delivered by FUA.

5.1.1.3 Collaborative Decision Making Aspects
To realise more fully the benefits of FUA by increasing the use of CDR1s and 2s requires collaboration between CFMU/CADF and AOs, so that the relevant information is not just provided, but is used to maximum benefit.

This is a low-level application of CDM, but it is important that such initial applications are put in place in the short-term, to provide the basis on which higher-level applications can be built in the longer term.

More generally, the FUA concept is a good example of two actors working together to improve the performance of the overall system without detriment to either. It is probable that even more can be achieved by adopting a wider collaborative approach in which the priorities of additional actors are considered and/or information flows are improved.

A higher-level and longer-term example is the Capacity Management process, where airspace reservations are optimised as a function of predicted traffic. Such a process is already foreseen [ATM2000+]. Benefits from making this process fully collaborative, and mechanisms for doing so, are discussed in section 6.1 of the present report.

An additional problem in the current system is that CFMU sets regulations before the CRAM is received, too early for CDR availability to be taken into account either in expected sector capacities or in predicted traffic load. However, this is likely to be corrected in time, as CFMU expects to move away from pre-tactical regulation-setting to a more responsive, tactical process which will be able to consider the actual airspace structure available.
5.1.2 Description of Process

5.1.2.1 Actors
The actors involved in this application are:

- **AOC** - responsible for filing flight plans;
- **IFPS** - responsible for receiving, processing and distributing flight plans;
- **CFMU/CADF** - responsible for compiling and distributing CRAMs;
- **Airspace Management Cells (AMCs)** - responsible for determining the availability of CDRs (as at present, with no change).

5.1.2.2 Information Flows and Processes
Two options are envisaged for the process required to achieve this application. These are illustrated in figures 5-1 and 5-2.

**Option 1:** Figure 5-1 shows the relevant information flows. All the information required for this option is already exchanged, although in the case of the CRAM to the AOC not necessarily used; this application concerns enabling that information to be used to full effect.

In order for CDRs to be used easily in flight planning, two changes would be needed from the current situation:

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*Figure 5-1: Information exchanges relevant to the use of CDRs in flight planning - option 1*
• AOs’ Flight Planning systems would need to be able to deal with conditional routes. This implies the ability to identify which routes are available today and select the preferred route from those. This could be done through look-up tables, but a more flexible solution would be provided by re-routing software (see section 5.1.6). Many flight planning systems would require modification.

• CRAMs would need to be in a form that could be processed automatically by flight planning systems, enabling those systems to update their databases of currently-available routes. This implies that the CRAM standard format must be rigorously applied, so that the messages are reliably machine-readable without the need for human intervention. Verification of the formatting of CRAMs would probably be necessary before they are sent. More importantly, standard meanings and definitions would need to be agreed and adhered to across all states, AMCs and FMPs. At present for example, what the UK system considers to be “a route” is not exactly identical to what is considered in France. This lack of consistency makes impossible standardisation of the degree that would be necessary for reliable automatic processing of CRAMs.

Option 2: Figure 5-2 shows the information flows of an alternative process that would enable increased use of CDRs in flight planning, without depending on upgrading of AOs’ flight planning systems.

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This raises a wider issue. Verification to ensure precise and reliable formatting of the many kinds of AFTN messages, both to and from CFMU and IFPS, would allow more automatic processing throughout the air traffic system.
The proposal is to introduce a new format of RPL and FPL, allowing each AO to file a choice of routes including CDRs, with options in preference order. Software in the IFPS would select for each flight the highest-preference route available on the day. That route would be written into the FPL for distribution to ATC and CFMU. The IFPS would inform the AO of the best available route, perhaps using the updated FPL.

If this new mechanism were used by all AOs, it would no longer be necessary for AOs to receive the CRAM for the purpose of route planning. However, it should remain available to AOs for information or other purposes.

5.1.2.3 Interfaces

Option 1: The required interface already exists: CRAM messages are sent by AFTN/SITA from CFMU/CADF to all AOCs. However, the reliability of formatting would probably need improvement, as described above.

Option 2: Again, the required physical interface already exist. A new format for RPLs and FPLs would need to be agreed, as described above. A new “route confirmation message” from IFPS to AOCs would be required, or alternatively confirmation of the best available route could be achieved simply by copying the updated FPL to the relevant AOC.

5.1.3 ATM2000+ Timescale

In terms of the ATM Strategy for 2000+, this application fits within the proposed improvements under Flexible Use of Airspace. It is proposed as a short-term application, for implementation within the timeframe 2000–2003. To achieve this, work should be initiated promptly.

5.1.4 Evaluation of Costs and Benefits

5.1.4.1 Areas of Cost and Benefit

No additional operating costs are foreseen.

A relatively small amount of investment would be required by each actor to develop the capabilities required for this application:

- by CFMU: to provide CRAMs in a fully standardised format (option 1), or to implement the new format for RPLs and FPLs, to update systems accordingly and to procure the route-selection software (option 2);

- by AOCs: to make the required extensions to their flight planning systems (option 1), or to develop route choices for each city pair and to update systems to comply with the new RPL and FPL formats (option 2).

The following benefits can be expected from increased use of CDRs:

- For AOs: reduced fuel costs, for flying a given schedule, through more efficient routing.

- For all parties: benefits from increased capacity arising from the more extensive exploitation of CDRs.

5.1.4.2 Metrics

A direct measure to indicate the success of this application would be:

- an increase in the rate of use of CDR1s and CDR2s, in flight plans as well as in actual use.

The resulting benefits could be assessed through the following metrics:
• the average daily or weekly fuel cost for flying a given schedule, or a given flight, over that period;
• the change in ATC capacity resulting from simplification of traffic flows as more traffic uses CDR1s and 2s\textsuperscript{7}.

When weighing up the cost of implementing this application against the benefits to be gained (particularly from the AOs' perspective) it should be taken into account that the new capabilities outlined here would subsequently enable further developments in the field of collaborative flight planning, allowing additional benefits to be realised later. In particular, re-routing software within Airline flight planning systems could also be used to choose less-congested routes to avoid delays. This possibility is discussed in sections 6.1 and 6.4 of the present report.

5.1.5 Dependencies
To encourage increased use of CDRs in flight planning, and to realise in full the capacity and flexibility benefits of FUA, CDRs will also need to be used throughout CFMU processes. Particular examples are:
• in IFPS for flight plan checking;
• in TACT for all regulation setting.

5.1.6 Problems and Further Studies Required
The following areas may require further study:
• Route-choosing algorithms for flight planning systems. EEC's CARAT project [ATFM WP] has already developed one example of such an algorithm.
• How best to ensure the formatting of CRAMs (and other AFTN messages).
• The most appropriate format for RPLs and FPLs to enable a preference-ordered choice of routes.

\textsuperscript{7} Increased capacity from the use of CDRs, via reduced workload per aircraft, has already been reported.
6. FLOW AND CAPACITY MANAGEMENT

Eight potential applications of CDM have been identified within the [ATM2000+] core process of Flow and Capacity Management. They are described in the sections 6.1 to 6.8.

- Collaborative Flow and Capacity Management. The objective of this application is to improve the effectiveness and efficiency of Capacity Management and Flow Management processes by combining them to form a collaborative process in which capacity and demand are co-managed by the actors. It proposes that pre-tactical and tactical Flow and Capacity Management should become a two-way process, where airspace organisation and traffic requirements are optimised in tandem, in response to one another, by close collaboration between the actors involved. Such a collaborative approach is considered essential to optimise the match between capacity and traffic demand and hence to minimise delays and disruption to schedules.

- Traffic Planning Model. Accurate forecasting is an essential element in moving from current demand-driven flow management to active capacity-management. This application concerns development and implementation of improved modelling techniques to support this, including use of archive and up-to-date information, and the exchange of forecasts to permit validation.

- Co-ordination between Airport Slot and ATFM. Co-ordination between the strategic airport slot allocation process and ATFM could be introduced in a number of possible ways. Such a collaborative approach to capacity management could alleviate the problems arising today from mismatches between these two, entirely separate processes.

- Re-routing. Re-routing flights at the flight planning stage to avoid congested areas of airspace can reduce delays to the re-routed flights as well as minimising traffic through the congested area. This is an example of a collaborative decision making process in Flow Management. The CFMU will within 1-2 years introduce a "What-If-Rerouting" capability which will enable alternative routes to be identified and planned.

- Slot Swapping. With Slot Swapping, airlines are offered greater flexibility in their tactical operations: they can swap slots between their flights provided that these flights are affected by the same regulations and provided the other flights are not penalised by the swapping.

- Substitution on Cancellation. This application aims at solving problems currently encountered in situations of major demand/capacity imbalance on airports (e.g. due to weather, technical failure...). Aircraft operators would be encouraged to cancel flights in a timely manner, by allowing them to re-use the cancelled flight’s slot for another flight. This should enhance fleet management for AOCs as well as flow and capacity management for service providers.

- Slot Shifting. Slot Shifting aims at encouraging airlines to declare early that they are going to miss a slot, so that this slot can be reallocated to another flight instead of being wasted. A flight declaring being late would not be "sent to the back of the queue" for the new slot allocation, but would get a slot as close as possible to the time at which it expects to be ready. Flights ahead of this new position in the slot allocation would (where possible) be shifted forward a few minutes to absorb the freed slot and make room for the delayed flight at its required time without delaying later flights.

- Airport Information for Flight Planning. Broadcasting of arrival and departure conditions at airports (SIDs, STARs, Runway in use, Weather conditions...) would help airlines improve their flight trajectory prediction and hence optimise their fuel load. With resulting better estimated times of arrival, management of turn-arounds should be also improved.
6.1 Collaborative Flow And Capacity Management

6.1.1 General Description

6.1.1.1 Context
At present, airspace structures are mainly static, being defined in advance. Flights are planned on the basis of that static structure, and Flow Control is applied when the capacity of the structure is insufficient for the expected traffic.

It is expected [ATM2000+] that improvements to the ATM system will support a progressive shift from this current practice of managing demand to match a fixed capacity, to a dynamic Capacity Management process in which Airspace Managers try to match capacity to demand, responding to and accommodating the changing traffic patterns. Capacity Management will be carried out in the pre-tactical and tactical phases, and will provide an optimal distribution of capacity at each time rather than a “best on average” solution. Examples of processes that might contribute to Capacity Management, as it is currently foreseen, are:

• replacement of the seasonal Traffic Orientation Scheme (TOS) with the dynamic Standard Routing Scheme (SRS);
• conditional routes may be incorporated within the SRS;
• increased scope of FUA.

Two longer-term possibilities are:

• dynamic sectorisation;
• tactical definition of Free Flight Airspace areas, in response to changing traffic densities.

Capacity Management on its own is not expected to be sufficient to ensure safe ATC capacity is not overloaded. Capacity is inevitably limited, and traffic tends to increase to equal and then exceed available capacity. Therefore a continued need is foreseen [ATM2000+] for tactical Flow Management as an additional planning layer, in particular for managing demand for airport capacity.

6.1.1.2 Objectives and Benefits
The objective of this application is to improve the effectiveness and efficiency of the foreseen Capacity Management and Flow Management processes by combining them to form a collaborative process in which capacity and demand are co-managed by those actors best placed to contribute.

It is recognised [ATM2000+] that a one-way Capacity Management process in which Airspace Managers try to match capacity to demand can never be fully adequate on its own, and hence that Flow Management will necessarily continue to impose delays on the users. This application proposes instead that Flow and Capacity Management becomes a two-way process, where airspace organisation and traffic requirements are optimised in tandem, in response to one another, by close collaboration between the actors involved.

Such a collaborative approach offers the airspace users increased operational flexibility and increased influence in the process of airspace and capacity management. A collaborative approach to Flow and Capacity Management is considered essential to optimise the match between capacity and traffic demand and hence to minimise delays and disruption to schedules.
The processes proposed here are intended to be carried out in the pre-tactical and tactical phases. However, it is also possible to envisage strategic collaborative processes to the same end (for example something similar to the co-ordination process for airports, see section 6.3).

### 6.1.1.3 Collaborative Decision Making Aspects

The process proposed is fully collaborative and involves delegation of decision-making to the actor best placed to take each decision.

### 6.1.2 Description of Process

#### 6.1.2.1 Actors

ATC Units (perhaps through their FMPs) would be collaborative partners in the process of Flow and Capacity Management, together with military operations planners and flight planners from civil airlines. Each should be an active participant in the process, with responsibility for jointly finding an optimal solution to their combined requirements, subject to their combined constraints.

It is envisaged that CFMU, or a similar central and independent organisation within EUROCONTROL, could act as a focus or “chairman” for the process.

The interactions between actors are illustrated, at a high level, in figure 6-1. The following section looks in more detail at how the process might work in practice.

![Figure 6-1: Interactions between actors in Collaborative Flow and Capacity Management](image-url)
6.1.2.2 Information Flows and Processes
The following paragraphs describe the steps envisaged in a collaborative Flow and Capacity Management process.

Initially, input would be required from AOs to define the demand. CFMU would use this to generate a traffic forecast. This forecast would be passed to Capacity Managers at ATC Units, who would also receive information from local Military Users about their airspace requirements. Each Capacity Manager would prepare a basic Airspace Management plan, based on the forecast traffic, military requirements and local airspace and manning constraints. Capacity would be provided wherever possible to accommodate the forecast traffic. Capacity Managers at neighbouring ATC Units would collaborate with one another, aiming to provide the required capacity across borders and ensuring continuity of Airspace Management plans.

So far, a straightforward Capacity Management process has been described. If this were the end of the process, it is likely that there would continue to be significant capacity shortfalls, leading to significant delays imposed on AOs. Instead, this application proposes collaboration between the actors to try to resolve the predicted areas of congestion.

Some military requirements will be non-negotiable constraints, while it may be possible to modify others without adversely affecting the planned operation. Similarly, each AO will have more-critical flight plans which it would rather not modify and less-critical flights which could be re-routed, re-scheduled, could use a different flight level, or could even be cancelled, if necessary to reduce congestion.

Both AOs and Military Users should be given the opportunity to look at the proposed ASM plan (including the proposed SRS), along with anticipated areas and levels of congestion. Each would then be encouraged to modify its requirements to take advantage of non-congested areas of airspace and times of day, and to relieve congestion where possible, thus avoiding delay. This could happen either on a pre-tactical or tactical timescale (i.e. the day before the day of operations, or on the day itself).

Two possible mechanisms are suggested. These are illustrated in figures 6-2 and 6-3.

Option 1. (See figure 6-2) The first possibility is that ATC Capacity Managers, AOs and military operations staff could collectively focus on the predicted areas of congestion to examine what might be done to relieve the congestion. This could be in an open forum, for example using techniques such as electronic whiteboards and video-conferencing. The negotiations would be based on proposals for changes to an actor’s own plan or to other actors’ plans, and on shared information on constraints and requirements (where possible without breaching commercial or military secrecy). AOs would be expected to modify or reduce their traffic demands at times and places where maximum capacity was exceeded, while ATC Capacity Managers would be expected to open up capacity where possible to accommodate demand (if necessary at the expense of capacity in less congested areas).

The fora could be arranged on a regional basis, but extensive co-ordination between the regions would be needed to ensure continuity of the solutions developed to alleviate congestion.

Option 2. (See figure 6-3) Alternatively, a process with two separate parts could be envisaged. In the first part ATC Capacity Managers would negotiate with local Military operations staff to attempt to free up airspace in congested areas and at congested times, in return for less critical airspace. In the second part, AO operations staff could be encouraged to modify their own traffic (for example, by re-routing, using different cruise levels, rescheduling or even cancellation) in order to reduce the level of congestion at blackspots and at peak times. These two parts might occur in either order, and there could be iteration of the two parts. The ASM plans would change to reflect changed military requirements and in response to changed traffic flows, so that a combined optimum is achieved.
The first part of the process in option 2 is similar to the current role of Airspace Management Cells (AMCs), and could be viewed as an extension to it. Neighbouring ATC Units (or AMCs) would need to co-ordinate throughout to ensure continuity of Airspace Management Plans across boundaries. It may be appropriate for a branch of CFMU to be involved in the ATC/Military negotiations where congested areas are cross-border.

It is envisaged that the CFMU would be responsible for liaising with the AOs in the second part of option 2. Again, congestion problems could be considered on a regional basis, but co-ordination between the regions would be needed to ensure continuity of solutions to congestion.

An initial implementation of Collaborative Flow and Capacity Management might consist of option 2, with no iteration either within or between steps 4 and 5 (see figure 6-3).

Note that, in either option, CFMU would need to retain authority to apply ATFM regulations for locations and times where the collaborative process had not been successful in matching capacity to demand. (This same authority is foreseen in the American implementation of CDM [FAA CDM]).
1. AOCs supply initial demand information.

2. CFMU predicts traffic and passes this prediction to ATC Units.

3. ATC Units’ “Capacity Managers” attempt to arrange capacity to meet the demand, subject also to Military Requirements.

4. ATC Units co-ordinate with local Military Users to attempt to resolve problems. CFMU involved where problem areas are cross-border. Message exchanges may be iterative.

5. AOCs encouraged to modify their traffic (e.g. by rerouting) to resolve remaining problems. The message exchanges may be iterative, and could proceed with or without supporting negotiation.

Steps 4 and 5 may occur in either order, and there may be iteration of these two steps.

6.1.2.3 Interfaces

Current interfaces will probably suffice for passing civil traffic demand and military requirements. Flow Management Positions (FMPs) currently receive traffic forecasts from CFMU, and the Capacity Management function could use these. However, new map-based displays and “what-if” tools to support Capacity Management are likely to be desirable.

Consider option 2 first (see figure 6-3). For the interface between ATC Units and Military airspace users, the starting point is the current FUA infrastructure, based on AMCs. The negotiation between an ATC Capacity Manager and local Military operations staff could probably be carried out by telephone initially. However, where numerous options are available, or in a future, less-structured airspace environment, shared map displays of airspace and “traffic congestion” (in some form) may be required. These would need to be supported by electronic data exchange.

All participating AOs would require access to flow management information, including traffic forecasts and Airport and ATC capacities, to show traffic congestion. This is currently available to many AOs through their “CFMU terminal” (RTA), but again, map-based displays would be required to make this information readily understandable.

For option 1 (see figure 6-2), map-based displays shared by all participants would be pre-requisite. These displays would show airspace, traffic and congestion. They would need to be supported by rapid and automatic exchange of information; time-consuming manual input must be avoided. A method of communicating proposals, constraints and requirements between actors quickly and simply would be required. This could be provided by techniques such as electronic whiteboards and/or video-conferencing.
6.1.3 ATM2000+ Timescale
Collaborative Flow and Capacity Management applies across two ATM2000+ areas of system improvement:

- Collaborative Flight Planning,
- Optimised Capacity Management.

Both these are foreseen [ATM 2000+] for about 2005. Therefore the combined, collaborative process described here is proposed for the longer term, commencing around 2008 or later.

6.1.4 Evaluation of Costs and Benefits

6.1.4.1 Areas of Cost and Benefit
Foreseen benefits of Collaborative Flow and Capacity Management are:

- **For AOs:** increased freedom of scheduling and increased flexibility in the handling of over-demand; minimised costs through optimisation of route/flight level/schedule/delay options for flights.
- **For ATC:** reduced likelihood of overloads through improved distribution of traffic.

Foreseen areas of cost are:

- Development costs:
  - Development and procurement of new displays and communications links required to support the process.
  - Development of new procedures.

- Operation costs:
  - Communications costs.
  - Possible additional staff cost for AOs, to support their increased involvement in Flow Management.
  - Possible additional staff cost for Military airspace users, to support their increased involvement in Capacity Management.
  - Possible additional staff costs for ATC Units and CFMU, although these may be negligible if Capacity Management replaces other Airspace Management and Flow Management tasks.

6.1.4.2 Metrics
In order to assess the cost-benefit of this proposed application, the above-listed costs would need to be estimated. The benefits could be assessed through the following metrics.

- Cost-efficiency of flights within a given schedule, taking into account both fuel costs and the costs of delays.
- Reduction in the incidence of overloads.

In addition, it would be relevant to investigate:

- whether delays were reduced for an AO flying a given schedule;
- airlines’ perceptions of increased flexibility in scheduling and operations.
6.1.5 Dependencies
This application (and indeed effective Capacity Management) depends on the availability of 
good pre-tactical or tactical forecasts of traffic. This issue is addressed in section 6.2 of the 
present report, Traffic Planning Model.

6.1.6 Problems and Further Studies Required
There are two main areas where work will be required in the development of this application. 
No priority order is implied; the two would probably need to proceed in parallel.

The first area is the development of displays and tools for Capacity Managers, AOs’ flight 
planners and Military operations planners, to support Collaborative Flow and Capacity 
Management. This might include:

- Displays to present airspace structure, capacity, traffic and congestion information.
- Techniques for rapid sharing of proposals and requirements, as proposed in option 1.
- Algorithms for finding optimal flight plans, within the prioritised constraints of available 
capacity and operational cost-effectiveness, and their performance in real time. (An 
example of such work is EEC’s CARAT project described in [ATFM WP]).
- Algorithms to assist Capacity Managers in optimising the distribution of capacity, within 
the prioritised constraints of demand, available airspace and manpower.

Prototyping of these tools and techniques will be important to ensure users’ needs are met.

The second area of work is the development of effective operational procedures. This can 
probably best be addressed by simple simulation trials, probably using prototype displays 
and tools as discussed above. Some of the questions to be investigated are:

- What the time limits for the process are; how late the last changes to airspace/traffic 
structure could be made.
- How many iterations (in option 2) would be required to reach a near-optimum solution.
- How competition between the airlines would affect their delegated Flow Management 
decisions.
- Whether and how GA should be included in the process.
6.2 Traffic Planning Model

6.2.1 General Description

6.2.1.1 Context
Accurate forecasting will be essential as we move from the current demand-management to active capacity-management. Furthermore, to allow effective collaboration in capacity management, accurate models of both predicted traffic and available capacity must be shared by all collaborating parties.

The information currently supplied by AOs is inadequate for forecasting because it is incomplete and inaccurate. Demand forecasting processes for flow management are principally based on the idea of extrapolating from previous year’s traffic levels by a chosen percentage reflecting the observed traffic growth. Some allowance is made for regional variations and unusual occasions, such as major sporting events, by modifying the load expected along the route(s) concerned. However, it is generally recognised that pre-tactical predictions are inaccurate, to the extent that AOs do not react to forecast pre-tactical delays.

6.2.1.2 Objectives and Benefits
The aim of this collaborative application is to produce improved traffic planning models by integrating further data from different sources, as and when that data can be available. Thus initially a coarse forecast would be produced by extrapolation of archive data, taking into account likely special events. Using appropriate algorithms, the initial forecast would be improved progressively moving closer to the day of operations by introducing new data when this became available.

The proposal is to examine integration of independent sources of data, such as travel booking organisations (GALILEO, AMADEUS...), AOs own data, national organisations data and the existing archive. This would have the benefit of providing a more reliable input to pre-tactical traffic forecasting, which is an essential step for the realisation of capacity management.

Thus ATM would benefit by having more reliable predictions on which to base operations.

In addition, the model results should be supplied to AOs with the aim that they should look at likely areas of delay and they would then be able to examine their own scheduling and start to revise it in the light of anticipated problems.

6.2.1.3 Collaborative Decision Making Aspects
The collaborative element of this application is essentially that ATM and AOs will jointly participate in developing the forecast, and a positive feedback loop will be developed to enable all to use the forecast to improve their own operations.

6.2.2 Description of Process

6.2.2.1 Actors
The actors who should contribute to this process are:

- **CFMU**, through archive data of actual flights. The archive data is the current basis for prediction, and provides an invaluable baseline from which to work.

- **AOs**, through their schedules, supplied through PFD and RPLs, and filed flights. The PFD and RPL data provides an expectation of airline activity, but will not normally be
complete or up-to-date since airlines’ operational plans evolve continuously up to the time of flight. However, this is the data currently sent to flow management for forecasting.

- **National administrations.** Where national administrations hold independent databases, these may well be useful as additional data sources. Also, national administrations may be in a better position than a centralised provider to provide forecasts appropriate to their local situation. Today this is achieved through FMPs.

- **Airports** have supporting information systems which could be a rich source of post-flight information.

- **Flight booking systems** - GALILEO, AMADEUS. The utility of this information has still to be proven, but it provides an independent source for the scheduled flights which the airlines expect to fly.

As an alternative to using the existing information provided by AOs and from flight booking systems, it could be made mandatory for AOs to provide, at given times, the best planning information they have available to CFMU. However, this would impose an additional overhead on the AOs and may give no better result than using databases already available.

### 6.2.2.2 Information Flows and Processes

Information exchanges are summarised in the following diagram:

![Diagram](image)

*Figure 6-4: Information exchanges for an improved traffic planning model*

The likely main information flows are to send the planning model data from the CFMU archive and the airline predictions of their own activity.
Once the forecast has been compiled, it will have to be distributed to the interested parties, particularly CFMU, FMPs/ATC centres and AOs. The forecast would be updated periodically as new data became available, and then these updates would also have to be distributed. A balance would need to be found between the frequency of updates and the benefits obtained, since, for example, there will be costs arising both from data transmission and making use of the data.

In terms of system requirements, the main constraint will be the relatively large volumes of data. Development might be carried out using standard workstations or PCs since processing time will not be a serious constraint, but for real deployment, more powerful facilities would certainly be needed.

### 6.2.2.3 Interfaces

Existing interfaces would probably be a good starting point for the development of this application, although new interfaces would be needed to be developed to obtain data from flight booking services.

Thus the archive database of the CFMU and the RPLs and PFD supplied to CFMU by AOs will be an important starting point. This will not require the development of new interfaces, although there may be work to bring together the databases concerned.

Once produced the forecasts would need tools to facilitate analysis, perhaps requiring different tools appropriate to each actor.

### 6.2.3 ATM2000+ Timescale

Optimised Capacity Planning, for which a good quality demand and capacity forecast is essential, is foreseen for implementation in about 2005 [ATM2000+]. However, the results of improved forecasts would be of use immediately, so it makes sense to initiate work as soon as possible.

### 6.2.4 Evaluation of Costs and Benefits

#### 6.2.4.1 Areas of Cost and Benefit

The main areas of cost are:

- telecommunications costs of transfer of information, although much of this happens already so the impact should be marginal
- development of capacity modelling and load planning tools

The main benefits will be:

- existence of a good traffic forecast will enable effective capacity planning, reducing the delays suffered by operators;
- operators will be better able to see areas where capacity is insufficient, and may be able to adjust their operating plans to compensate and thus reduce the impact and hence cost of insufficient capacity.

#### 6.2.4.2 Metrics

Possible metrics are:

1. Quality of predictions against actual traffic. Pre-tactical and tactical predictions of traffic demand should be compared against the flight plans actual filed by airlines, and against records of flights actually flown. Various dimensions should be measured, such as using
a window of defined time-width to try to capture flights at nearly the same times. A comparison should be made with the effectiveness of the current forecast+increment approach. This metric is necessary in order to know whether the additional data actually provides a sufficiently different result to warrant the required investment. As well as the quantitative measure, more qualitative input regarding the "usefulness" of the new predictions as perceived by users should be obtained.

2. Cost of data collection. It is necessary to determine if the results obtained are obtained in a cost-effective way.

3. Coverage. A further possible metric is the proportion of flights for which information is not actually captured.

6.2.5 Dependencies
The principal dependencies for the work are the availability of the required data with sufficient coverage, requiring support of enough AOs.

Links should be considered to any task concerned with strategic and pre-tactical planning.

6.2.6 Problems and Further Studies Required
At present the kind of information that is required is distributed across several different computer systems and databases, and exists in many different formats. The data would have to be analysed in co-operation with the potential data suppliers in order to determine whether it is feasible to find a common format for combining the data.

As a part of this, there should also be investigation of data volumes and costs.

The second main task will be to develop algorithms needed to integrate data obtained to form an improved prediction of the flights that will be flown. For this, the key area is appropriate data processing, which may well involve the application of sophisticated software engineering techniques. The most appropriate techniques must be identified. There will be numerous traps in the data to deal with. For example, overlaps must be identified and it must be determined if they are real overlaps in which case eliminate them, or if they are different flights, in which case they would have to be retained.

The third main task is to develop a process which can be used for benchmarking, i.e. to compare the results of possible algorithms with the actual events so that the results can be validated.

Problems to resolve include: precise choice of automated processing techniques and algorithms, identification of sources of data, stability of data sources,.....

Study of information processing techniques, including:

- fuzzy logic algorithms
- AI software products
- data mining software (based on existing archive database?)

An investigation should be made of the possible techniques (e.g. literature survey).

Implementation would need to be a step-by-step evolutionary process. It may be appropriate to progress by introducing extra sources of data one at a time.
6.3 Co-ordination between Airport Slot and ATFM

6.3.1 Context
At present, airport slots and flow management slots are not co-ordinated. This can lead to several different problems. For example, the airport may allocate too many take-off or arrival slots relative to the local ATC capacity, with the result that sectors may regularly be overloaded and flow managers may need to impose delays.

A collaborative approach of improved information exchange might alleviate this.

6.3.2 Description
Airport slots are currently allocated through the bi-annual IATA conference. During this allocation process, steps could be taken to ensure that the airport slot is matched by the potential to assign a flow management slot given the expected ATC capacity. Alternatively, at a co-ordinated airport, flow management might only be permitted to assign flow management slots to flights with airport slots. Several related issues need to be considered: for example, the effect on flights coming from or going to non-coordinated airports.

Preliminary consideration suggests that this would be a longer-term implementation of CDM, perhaps from about 2008. It would fall within the “integrated slot planning” initiatives [ATM2000+].
6.4 Re-routing

6.4.1 Context
This proposal relates to rerouting of flights at the flight planning stage.

Re-routing is possible at present within the current ATFM structures, but it requires a great deal of work from ATFM and the AOC concerned. The AOC will normally try to find a better route only in response to a large take-off slot delay being given by the CFMU, so the rerouting is carried out after Slot Issue Time (2 hours before EOBT). The objective will be to reduce the delay to try to fit into the airline’s delay statistics criteria (e.g. "on-time" means within 15 minutes of scheduled take-off time). Typically the process followed is to submit a dummy flight plan to test the alternative route and then to cancel the old flight plan if the dummy flight plan shows a slot with a lesser delay.

6.4.2 Description
The process of negotiating improved slots and routes through rerouting tools is widely regarded as a collaborative application.

The CFMU will within 1-2 years introduce a "What-If-Rerouting" (WIR) capability which will enable AOCs to find alternative routes for individual flights; as currently conceived the WIR facility will provide a proposal for an alternative route which the AOC will have a short time to accept or reject, most likely through an automated system.

The EEC project CARAT is involved in experimental development of rerouting algorithms and methods [ATFM WP].

Since there is considerable activity already going on in this area, for its implementation in the near term, this application will not be developed further by this project at this time.

Flight level restriction represents another form of “rerouting”. Reducing the planned cruising level for some or all of the flight can allow a flight to remain beneath a congested sector or area of airspace. In order for full use to be made of this mechanism, modifications may be required to allow the CFMU system to model more than a single cruise level (for example, a delayed final climb, or an early descent).

A longer-term development of re-routing is considered in the Collaborative Flow and Capacity Management application described in section 6.1 of the present report.
6.5 Flight Prioritisation 1: Slot Swapping

6.5.1 General Description

6.5.1.1 Context

In the current CFMU process, slot allocation defines the exact order in which aircraft will penetrate regulations. It is based on the “first scheduled at the regulation, first served” principle. This principle is obviously equitable, and therefore appropriate while a single, central agency (CFMU) is solely responsible for making decisions about slot allocation. There are a number of circumstances where operational benefit could be gained from adopting a more collaborative approach to slot allocation, allowing prioritisation of certain flights by AOCs within conditions agreed by all to ensure fairness. This application considers one example, that of slot swapping, which could bring significant operational benefits to airlines.

Suppose an airline has two flights with the same cruising speed departing from the same airport with about the same schedule and going through the same (single) regulation but bound for different destinations. The two flights will depart in the same order as that in which they were scheduled to penetrate the regulation. Suppose one of the flights is a commercially sensitive flight but is the most delayed by slot allocation. At present, the airline may telephone a CFMU operator to ask if he can swap slots between the two flights and thereby have the commercially sensitive flight depart with the less penalising slot. CFMU approval to swap slots is necessary because one must check that changing the order of these flights does not cause problems in other parts of the airspace through which they pass.

This need for manual intervention to swap slots means that it is very time-consuming and hence can only be considered in occasional, exceptional circumstances. This does not offer the airline the operational flexibility it needs.

6.5.1.2 Objectives and Benefits

The objective of slot swapping is to give airlines the possibility to change the order of departure of their flights going through the same regulations at about the same time. In other words, airlines will be able to prioritise flights over others within their own set of flights.

One could envisage implementing an automated process for the airlines to request slot swapping within the current CFMU-AOC message exchange mechanism. Feasibility of the swapping would be automatically checked by a tool in the TACT system and a message of approval or rejection would be sent to the airlines. By feasibility we mean that other flights going through the same regulations are not penalised by the swapping. Such a tool would reduce the time and effort needed by the CFMU operator to approve or reject each request.

The scope of slot swapping could be extended thanks to the automation of the process. It could be applied to flights that have a common most penalising regulation but that go through different regulations after or before the most penalising one. This is discussed further in section 6.5.6.

6.5.1.3 Collaborative Decision Making Aspects

It is clear that only the CFMU can approve or reject slot swapping requests because it is the only actor to have a comprehensive view of the traffic. But the process will be efficient only if airlines have access to information that will help them make a realistic swapping proposal that has every chance of being accepted. Providing this information to the airlines, with a
user friendly display in order to make their operations more efficient, is in essence a collaborative process.

6.5.2 Description of Process

6.5.2.1 Actors

Airlines will be part of the process mainly via their operations control centres. The operations control centre monitors slot delays and tries to improve the departure time often by re-routing actions. In co-ordination with the commercial department, the operations centre knows which flights are the highest priority for take-off time improvement.

The operations control centre will decide which flights should be swapped and send a request to the CFMU. It will confirm approval messages from the CFMU for slot swapping.

CFMU receives the slot swapping request and checks that it is feasible as defined in section 6.5.1.2. If the swap is approved and confirmed by the airline, the CFMU then sends updated FPL to all ATC units concerned as well as to both departure and arrival airport authorities.

6.5.2.2 Information Flows and Processes

Information flow:

![Figure 6-5: Information exchanges in slot swapping](image-url)
Dynamics:

1. AOC sends slot swapping request to the CFMU.
2. CFMU sends AOC slot swapping message.
3. AOC sends confirmation if swapping approved.
4. CFMU sends updated FPL to ATS and airport authorities.

6.5.2.3 Interfaces

Information display on CFMU terminal: Flight profiles on maps of sectors, highlighted regulated sectors, time of entry of aircraft in sectors as a minimum.

Slot swapping request: Call-sign of actual earliest flight, call-sign of actual latest flight.

Slot swapping message: Call-sign of actual earliest flight, call-sign of actual latest flight, approval or rejection.

Acceptance message: Call-sign of actual earliest flight, call-sign of actual latest flight, yes or no.

6.5.3 ATM2000+ Timescale

This application of CDM can be considered for initial implementation in the short term (2000–2002) perhaps as part of the “Enhanced Tactical ATFM” system improvements [ATM2000+]. Extending the scope of slot swapping to include flights going through the same most-penalising regulation but different other regulations could be a medium term goal.
6.5.4 Evaluation of Costs and Benefits

6.5.4.1 Areas of Cost and Benefit
Aside from the airlines, no other beneficiaries of slot swapping seem to exist. The main benefit for the airlines would be the possibility to prioritise their flight.

Three main sources of cost have been identified.

First, in order to have efficient access to information that would help them to swap slots, airlines would need to invest in a CFMU terminal. All airlines do not have such a terminal at present.

Second, use of the information and prioritisation of flights would probably require additional manpower inside the airline. This why it is important that the display of the information should be clear and should not require too much additional processing from the airline.

In the total implementation cost of the process as seen from the CFMU side (third source), the cost of development of the information display may be minimised thanks to the fact that it would probably have many common features with the display available for the what-if re-routing. A what-if swapping tool could even be envisaged.

6.5.4.2 Metrics
CFMU ATFM delays as defined by CODA should not increase because of the slot swapping. This might be prevented if marginal costs [ATFM WP] of flights after swapping can be evaluated and compared to their values before swapping. If the sum of the variation of the costs is positive then swapping should not be allowed.

The number of swaps should be recorded. A balance must be obtained in the sense that slot swapping must be used sufficiently often for airlines to gain benefits but must remain marginal compared to global ECAC traffic, because otherwise efficiency of flow management will decrease.

6.5.5 Dependencies
As far as the request and approval/rejection messages are concerned the process will use the existing message exchange mechanism between Airlines and the CFMU. But the information display for slot swapping will need to be either created from scratch or based on the what-if re-routing display.

6.5.6 Problems and Further Studies Required
Wherever the “first come first served” principle is compromised, it is necessary to ensure that benefits are distributed in a way that operators agree is fair, and that no-one is disadvantaged overall. The “ground-rules” would need to be agreed by all parties. Collaborative involvement of the AOCs in the process will then ensure that it is visible to them, so they can be confident of a fair outcome.

The slot swapping described above is the particular case of a general situation where airlines could swap the order of any flights going through one or more regulations at about the same time. By “any flights”, this means flights not necessarily departing from the same airport. Moreover, the common regulation may be an en-route regulation or a regulation on arrivals. Figure 6-7 illustrates a range of possible cases.

- Case 1: both flights go through only one regulation (described above).
- Case 2: both flights go through one or more identical regulations before/after the most penalising one.
• Case 3: each flight goes through different regulations before/after the most penalising one.
• Case 4 is a combination of Case 2 and Case 3.

Which cases can realistically be implemented would need to be defined in the course of the application development. For each case, different types of regulations should be considered: en-route, TMA and arrival.

One could even envisage slot swapping between flights of different airlines. But this raises more issues than the one already discussed here and should be considered as a very long term goal for this application.
6.6 Flight Prioritisation 2: Substitution on Cancellation

6.6.1 General Description

6.6.1.1 Context
This application is intended to apply in situations of significant demand/capacity imbalances on an airport, e.g. due to technical failure, weather situation or industrial action.

In these situations, it appears today that ATFM measures are not very efficient and that the slots are not well respected. In case of bad weather, airlines are tempted to take off hoping that, by the time they reach the destination airport, the situation has improved. As a result, more traffic arrives than the arrival capacity can cope with. This leads to excessive holding around the airport. In time the effects spread outwards from the airport, perhaps eventually leading to en-route holding to protect the overloaded TMA sectors. Delays increase, but airlines hesitate to cancel their flights, firstly because they are likely to lose their passengers to a competing airline, and secondly because it would just free their ATFM slot for a competitor.

In today’s system, there are already specific disruption situations where flights are exempted from CFMU slots in order to improve the flow of traffic. An example is given by the de-icing procedures recently agreed by the EAMG Operations Sub-Group [EAMG].

6.6.1.2 Objectives and Benefits
The idea is to assign, temporarily, to an airline all the ATFM slots currently allocated to its flights arriving at the disrupted airport. The airline would then be able to chose how best to use those slots to manage its own schedule against the disruption. It could chose to cancel a flight going to this airport and use the ATFM slot to reduce the delay to another, more critical flight which originally had a later slot. The later, unused slot would be “handed back” to the central pool, where it would again become available for other users in the True Revision Process.

Experience in the USA with the Flight Schedule Monitor (FSM) developed by Metron Inc. for the FAA [FSM], has demonstrated significant benefits [FAA CDM]. Airlines operating a hub at the affected airport are in the best position to make use of this facility, since they have to possibility to regroup passengers on other flights. Participating airlines are encouraged to cancel flights into the disrupted airport because they now get direct benefit from doing so: their schedules are protected because they can avoid severe delay for their most critical flights. Other AOs benefit because the arrival traffic into the disrupted airport is reduced, reducing the delays for all operators.

In contrast to the swapping possibilities, the participating airline would be allowed to substitute one of its own flights for the cancelled flight even if the two flights were not subject to the same en-route regulations (see section 6.5 for further discussion of slot swapping).

This would have one negative and one positive impact for ATC:

- risk of dispersion: it may create bunching in en-route sectors due to the fact that a flight gets a better slot after substitution and is forced in other en-route regulations;
- global decrease of the number of flights and better traffic load forecast for sectors surrounding the disrupted airport (since participating airlines are encouraged to cancel flights). This may have the effect of alleviating excessive holding around the airport and resulting en-route holding.
6.6.1.3 Collaborative Decision Making Aspects
The collaborative aspects of this application are straightforward. Here, the internal priorities of the airlines (due to hub operations, specific flights etc.) are to be taken into account in the slot allocation and revision process: the decision is made where it makes the most economical sense.

6.6.2 Description of Process

6.6.2.1 Actors
Airlines: The airline receives information about its ATFM slots and the general situation on the airport (current and predicted weather etc.). It has to organize an internal process in order to determine priorities and to select flights which may be cancelled (for example, because the delay is too high, or there is a limited number of passengers or the passengers can be transferred to another flight).

CFMU and FMPs: The CFMU has to process the cancellation and substitution information so that all ATFM and ATS systems are informed of the new slots (so that the flight will be released by the departure airport and the delay figures will be accurate). It may check the feasibility if required.

The FMP monitors the impact of the substitution and informs the CFMU or the airline of any arising problem.

6.6.2.2 Information Flows and Processes

Figure 6-8: Information exchange for Substitution on Cancellation
6.6.2.3 Interfaces
As far as the airline is concerned, the only information required is already available: the ATFM slots of its flights. It is also necessary to implement a function which allows the airline to transfer its slot from one flight to another.

It must be decided if this function is implemented within a CFMU terminal or via a CEU operator.

The information concerning the cancellation/substitution must appear on FMP terminals so that FMP controllers can monitor, analyse and understand deviations from the standard rule “first planned, first served”.

It must also be available to the departure airport so that the substituted flight will be released in time.

6.6.3 ATM 2000+ Timescale
This application of CDM is proposed for implementation in the shorter medium term (2002–2004) perhaps as part of the “Enhanced Tactical ATFM” system improvements.

6.6.4 Evaluation of Costs and Benefits

6.6.4.1 Areas of Cost and Benefit
Potential benefits for ATFM provider: more accurate representation of the real situation (compared with today’s situation where slots are not well respected).

Potential benefits for the ATS provider: better traffic forecast (as above) and decrease in the number of flights arriving at the disrupted airport, leading to decreased need for holding around the airport and for en-route holding.
Potential benefits for the airline which cancels a flight: better predictability and fleet management, lesser delays for designated flights, better schedule management.

Potential benefits for other airspace users: decrease in the number of flights arriving at the disrupted airport means that global level of delay decreases.

6.6.4.2 Metrics
It will be difficult to compare the result of this procedure to what would have happened without its implementation. Nevertheless, it should be feasible to focus on the following metrics:

- number of flights cancelled using this procedure;
- reduction of delays for flights substituted to other flights;
- global reduction of delay for the concerned regulation;
- bunching in en-route sectors associated with the procedure;
- occurrence of en-route holding in cases of decreased capacity at airports.

It must be stressed that the benefits should be evaluated against the current situation: concentration of delay in a specific time period and location, airport terminal disorganisation etc..

6.6.5 Dependencies
The cancellation/substitution process might be seen as a specific case of slot swapping (see section 6.5). Nonetheless, it might be seen as more acceptable:

- to the user community with regards to equity as non-participating operators will ultimately benefit from the procedure;
- to the ATS providers as the negative impact of these procedures on flight predictability is compensated for by the reduction in the number of flights in delicate traffic situations.

As such, it could also be implemented in nominal traffic situations if deemed suitable.

6.6.6 Problems and Further Studies Required
In order to evaluate the respective effects of the procedures, that is flight dispersion and improved predictability, it is necessary to simulate them for various plausible traffic situations. These simulations will help ensure that the overall impact of the application is positive and clarify its mechanisms for all concerned actors. Among others things, it will be necessary to ensure that gains coming from cancellation/substitution are retained after a general recalculation of the slots (if the arrival rate changes).

Since the outcome of the simulation relies on the strategy of the airlines which itself may rely on the strategy of other airlines, it is appropriate that a set of behaviours be defined and simulated. To this end, the participation of AOC dispatchers will be encouraged.

In addition to the above, the cost-benefit analysis will have to be based on the number of occasions when the procedure would prove useful (at how many airports and on how many days?).

Finally, the simulation may provide some experience regarding the application of the procedure by the airline: will it be manual and totally based on human intervention, or is it possible to define criteria for flight cancellation/substitution which might be used to develop a specific HMI?
The timeframe for the decision has also to be carefully evaluated: the airline must be encouraged to cancel flights, where appropriate, as soon as possible, in order to trigger a snowball effect and to optimise the use of available capacity. It has to be evaluated whether the slot freed by the flight which takes advantage of an improvement can be used for another substitution and what is the deadline to make use of it.
6.7 Slot Shifting

6.7.1 General Description

6.7.1.1 Context

In the present system, a small but not insignificant proportion of allocated slots are eventually not used. One of the reasons for this is that a departure that is running late (e.g. because of technical problems, a delay on arrival, or baggage-handling delays) may not “hand back” the CFMU slot it is about to miss in time for that slot to be reallocated to another flight.

No mechanism now exists to encourage airlines to inform the CFMU of unused slots as early as possible. This is particularly true during the pre-departure phase of a flight. Airlines have the possibility to send a slot revision request to the CFMU stating the next EOBT achievable within EOBT - 2 hours. But if they do so, the flight will be put back at the end of the queue when allocated a new slot. The result, according to airport controllers interviewed in the FASTER project [FASTER], is that airlines tend to wait until expected push back time to inform ATC that they will be late for their slot. If they report a problem sooner and ask for another slot which they can be sure of meeting, they may get a slot that will delay the flight even more. Hence, there can be an incentive for airlines to take the chance that they will be able to solve their problem in time and make the slot (with the risk of missing it and then being delayed), rather than inform CFMU of the problem early and be delayed for sure.

When a flight is against the limit of its slot time, ATC may try to negotiate a slot extension with the CFMU and ATC/Airport Authority may try to prioritise ground operations to help the flight, but this is done at their discretion and to a limited extent. Such practices could not become too common considering the increase of controllers’ workload and the disorganisation (and hence increased likelihood of sector overloads) it would lead to.

A more collaborative approach to slot allocation in the case of delayed departures could help to minimise the number of slots that go unused, and hence to minimise wasted capacity.

6.7.1.2 Objectives and Benefits

Within this context, it is proposed to investigate developing a process that would encourage airlines to release as early as possible slots they are likely to miss. This can be done by reducing, ideally eliminating, the effective penalty (in terms of delay) they receive from doing this.

The proposed mechanism is, in simple terms, that the delayed flight would let the next few flights through the regulation “go in front of it” in the slot “queue”, establishing its new place in the queue at the earliest time it could realistically achieve. This contrasts with the current situation where the delayed flight is simply sent to the back of the queue.

Slot shifting is proposed as a complement to the slot extension process already used by the Tower to allow a flight which has missed its slot to take-off without a new slot. However, it may reduce reliance on that process, thus reducing the workload and the increased risk of overloads that slot extension implies.

Earlier reports of delays will also help Airport Authorities in a more efficient use of their infrastructure. Accuracy of stand allocation planning will be increased. Likewise, this process will help the Tower optimise the departure sequence.

Slot shifting is also a complement to the applications Estimation of Take-Off Time and Estimation of Off-Block Time described in sections 8.2 and 8.3—it will help improve the
estimate of off-block time as airlines will be more prepared to declare any delay and giving their EOBT will not be a tactical issue for them any more. Improving the accuracy of EOBT will in turn improve the accuracy of ETD.

It is possible that slot shifting may smooth out the slot allocation bunching effect on short-haul flights, as airlines will tend to declare earlier that the return or subsequent flight will not meet its slot.

### 6.7.1.3 Collaborative Decision Making Aspects

With slot shifting, Airlines collaborate with ATFM to ensure that no capacity is wasted; they know that if operations during turn-around are delayed, it is in their interest to inform ATC/ATFM/AA and release their slot, taking a later slot that they will be able to meet. Airlines will be the main beneficiaries of this process: the AOC of the delayed flight has improved operational flexibility and probably a reduced delay. Airlines of other delayed flights of the same queue also receive reduced delays because the slot has been freed.

### 6.7.2 Description of Process

#### 6.7.2.1 Actors

**Airlines** will be part of the process mainly via their operations control centres but also via the pilots and station managers.

- The operations control centre is always informed of delays, because it monitors events and is responsible for resolving problems through internal co-ordination (handling, maintenance, personnel…) or external co-ordination (e.g. monitoring and management of the slots allocated by the CFMU). The operations control centre will define a new EOBT at which the delayed flight will be ready. It will request a slot revision within defined time limits to the CFMU with the information on the new EOBT and the corresponding FPL.

Inside the airline there are other actors who are also likely to make the slot revision request:

- the pilot: he/she often knows better when the problem will likely be solved since he/she is on site. After approval of his/her operation centre, he/she will make the request to the airport ATC which will relay it to the CFMU.

- the station manager: like the pilot, he/she often knows better when the problem will likely be solved since he/she is on site. After approval of his/her operation centre he/she will make the request using the appropriate interface (SITA or CFMU terminal) in co-ordination with the pilot.

**CFMU** receives the slot revision request and tries to accommodate it by allocating a slot to the flight that best matches the requested new EOBT. It sends a slot revision message to the airline. If the airline accepts the revision, the CFMU then sends updated FPL to all ATC units concerned as well as to both departure and arrival airport authorities. It releases the unused slot and allocates it to another flight.

**Airport ATC** will relay any slot revision request asked by pilots to the CFMU. When the FPL is updated by the CFMU, it will inform the pilot of its content.
6.7.2.2 Information Flows and Processes
As identified in the above section, three types of actors can request a slot shifting: the AOC (option 1), the pilot (option 2), the station manager (option 3). The corresponding information flows and processes are described below for the different options.

Option 1: the Airline Operation Centre requests a slot revision.

Information flow:

Figure 6-10: Information exchanges for Slot Shifting - option 1
Dynamics:

1: AOC sends slot revision request to the CFMU
2: CFMU sends AOC slot revision message
3: AOC sends acceptance
4: CFMU sends updated FPL to ATS and airport authorities

Figure 6-11: Proposed process for Slot Shifting - option 1
**Option 2:** the Pilot requests a slot revision.

**Information flow:**

![Diagram showing the information flow for slot shifting - option 2](image)

*Figure 6-12: Information exchanges for Slot Shifting - option 2*
Dynamics:
In this case, the revision process involves mainly the pilot, ATC and the CFMU.

1: After co-ordinating with AOC, pilot sends slot revision request to ATC at ADEP.
2: ATC relays request to CFMU.
3: CFMU sends new CTOT, EOBT to ATC at ADEP.
4: ATC relays new EOBT, CTOT to the pilot.
5: Pilot accepts, and relays new EOBT, CTOT to AOC.
6: ATC relays acceptance to the CFMU.
7: CFMU updates FPL and sends it to all concerned.

Figure 6-13: Proposed process for Slot Shifting - option 2
In the alternate case, pilot, ATC, AOC and CFMU are involved.

1: After co-ordinating with AOC, pilot sends slot revision request to ATC at ADEP.

2: ATC relays request to CFMU.

3: CFMU sends slot revision message to AOC.

4: AOC accepts the revision.

5: AOC relays new EOBT and CTOT to pilot.

6: CFMU updates FPL and sends it to all concerned.

**Figure 6-14: Proposed process for Slot Shifting - option 2, alternate case**
Option 3: the Station Manager requests a slot revision.

Information flow:

Figure 6-15: Information exchanges for Slot Shifting - option 3
Dynamics:

1: After co-ordinating with AOC, Station Manager sends slot revision request to CFMU

2: CFMU sends station manager slot revision message

3: Station manager accepts SRM, and relays new EOBT, CTOT to AOC

4: CFMU updates FPL and sends it to all concerned

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<th>CFMU</th>
<th>ATC at ADEP</th>
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**Figure 6-16: Proposed process for Slot Shifting - option 3**

6.7.2.3 Interfaces

Only the interfaces for option 1 (the AOC makes the shifting request) are described here. For the other options (shifting requested by pilot or station manager) the content of the exchange is the same but the means of communications maybe different.

**Slot revision request:** The content is identical to the one described in page 10 of the [ATFMGuide]:

- Call-sign, Departure Airport, Arrival Airport, date of flight and new EOBT required.

**Slot revision message:** The content is identical to the one described in page 6 of the [ATFMGuide]:

- Call-sign, Departure Airport, Arrival Airport, date of flight, new EOBT, new CTOT and the most penalising regulation.

**Acceptance message:** call-sign, yes or no.

One should keep in mind that although the process uses existing mechanism for the information exchange, the slot allocation rules differ from the present ones.
6.7.3 ATM2000+ Timescale
This application is proposed for shorter medium term implementation (around 2003 to 2005) within the [ATM2000+] initiatives on Collaborative Flight Planning and/or Enhanced Tactical ATFM.

6.7.4 Evaluation of Costs and Benefits

6.7.4.1 Areas of Cost and Benefit

Benefits: The first benefit is expected to be for the AOs. It will be easier for the airlines to keep up with their schedule if they are a bit late on one leg, since they will not be penalised by releasing a probable missed slot. In this way, flexibility of their operations under ATFM will be improved.

The second expected benefit from the process is a decrease of the number of unused slots. This is expected to result in more even and predictable flow rates, although it not in practice result in a capacity increase: regulations are often set based on practical experience rather than on the precise flow rates (controllers and flow managers know that a regulation of 28 gives a manageable traffic flow under given conditions, although they know that they may get more than 28 aircraft an hour through the sector). So if fewer slots are unused, flow managers will have to set a lower regulation to achieve the same manageable flow.

Costs: Except for communications costs, no running costs have been identified so far. There will be some development and implementation costs.

6.7.4.2 Metrics
The following metrics are proposed to evaluate the benefits of the slot shifting process:

- delays:
  - for each slot shift, the delay increase incurred by aircraft of the same slot queue as the shifted flight, or possibly marginal costs;
  - CFMU ATFM delays as defined by the Central Office of Delay Analysis;
- bunching index [ISA];
- number of times per day the process is used;
- number of unused slots.

6.7.5 Dependencies
No prerequisites are required to implement this process since it will use communication means that already exist between Airlines and the CFMU. Still the benefits of this process could be improved if

- ground operations and especially gate planners at airports had information on slots and CFMU computed off-block times, which is not the case everywhere,
- station managers can communicate with the CFMU.

6.7.6 Problems & Future Studies Required
Because flights will not be put back at the end of the queue if they are granted a slot shift, new rules to allocate slots to shifted flights will have to be defined. These rules will not follow the “first over, first served” principle. These rules must be agreed by all aircraft
operators to ensure their fairness. This will be possible only if airlines are involved during the development phase of the process.

Simulation of the slot shifting process will be necessary in order to:

- Assess its impact on delays;
- Fine tune the limits in which the process will be allowed:
  - shift limits,
  - time limits,
  - number of times the process can be used for the same flight,
  - what happens if the regulation changes...;
- Check that the process is robust to cheating.

In a first phase, only computer simulations need to be performed. An airline behaviour model reflecting different operational strategies will need to be developed to simulate as many airlines as needed. If the AMOC/TACOT facilities and a sample day of traffic are used, knock-on delays will be generated automatically. Yet defining a set of representative events of delays internal to the airlines will be tricky. The breakdown of the delay causes along with the percentage of flights concerned also given by the airlines within the FASTER project [FASTER] is good data to start with. But how it should be transformed into realistic random occurrences of delays during the simulation is something to look deeper into.

Scenario development and computer simulations should also focus on how the slot shifting process could be used to abuse the system and what would be the consequence on traffic flows and delays.

If computer simulations prove the process technically and economically viable, live trials involving airlines’ operations controllers will need to be carried out to certify it. An on-line observation period may be needed in order to show airlines the benefits of the process operated as a self-policing system.
6.8 Airport Information for Flight Planning

6.8.1 General Description

6.8.1.1 Context
During the pre-departure phase, the AOC and the pilot are looking for accurate information about the flight in order to prepare the operational flight plan. In particular, they have to decide on the amount of fuel to be loaded for the flight.

The anticipated knowledge of departure and arrival conditions (SID, STAR, runway in use) would allow the AOC to minimise the loaded fuel: as no information is typically available today, the AOC considers the maximum flight length, taking into account the SID and STAR giving the longest flight path.

6.8.1.2 Objectives and Benefits
The objective of this application is to provide the AOC and the pilot with regularly updated data on the flight conditions: SID, STAR, runway in use at departure and arrival airports. The benefits expected are the following:

- Minimisation of the loaded fuel, by loading just the right amount for the SID and STAR. No additional contingency fuel other than for holding and diversion is loaded. The amount of fuel saved is the contingency fuel taken in case the most penalising SID and STAR must be followed. It might appear a very small saving for each flight, but over many flights is in fact sufficient that airlines have requested this airport information [FASTER].

- Improvement of the flight trajectory prediction and therefore accurate calculation of ETAs and flows into control sectors.

The principal objective of this application is the optimisation of the flight using existing data, during pre-tactical phase.

A second objective is to help organise turnarounds thanks to a more accurate knowledge of ETAs.

6.8.1.3 Collaborative Decision Making Aspects
This application relies mainly on the use, at the right time, of existing data. It could lead to collaborative planning if the AOC, once it has used the airport information for flight planning, returns the updated flight plan data to other interested parties. (cf. applications on Arrival Management (sections 7.3 and 7.4) and In-Flight Traffic Management (section 7.2)).

Examples of collaborative processes enabled by the use of FPL updated by the AOC are:

- use of updated ETA
  - by ATC for arrival sequencing,
  - by the AA for co-ordination/optimisation of allocation of stand or apron and runway;

- collaboration between CFMU or ATC and AOC in trajectory prediction, as discussed in other applications (Departure Management (sections 8.2, 8.3, 8.4), In-Flight Traffic Management (section 7.2), Distribution of AO/Aircraft Flight Plan Information (section 7.1), Arrival Management (sections 7.3 and 7.4)).
6.8.2 Description of Process

6.8.2.1 Actors
The actors involved in this application, and their respective responsibilities are:

- **ATC at the departure airport**: giving SID and runway in use to AOC;
- **ATC at the arrival airport**: giving expected STAR and predicted runway in use to AOC, together if possible with assessments of confidence in the predictions;
- **AOC**: receiving SID/STAR/runway data and using them in their operations control and dispatch processes, returning updated FPL and ETA;
- **CFMU**: receiving updated FPL.

6.8.2.2 Information Flows and Processes

**Information Flow:**

![Diagram of information flow](image)

**Figure 6-17: Information exchange for providing Airport Information for flight planning**

Proposed new elements are:

- Information on expected SID, STAR and Runway in use. The information could be co-ordinated by each airport or may be centralised at European level.
- Estimation of reliability of SID / STAR / Runway information: is it stable enough compared to flight duration.
- Updated FPL, including accurate ETA.

**Dynamics:**

![Diagram of proposed process for providing Airport Information for flight planning](image)

Information could be centralised before transmission:
- Airport data may be centralised for AOC to access as required;
- FPL updates and distribution may be co-ordinated or centralised (e.g. through CFMU/IFPS, through a new information management centre, or through ATC in charge of the flight at the time of update).

### 6.8.2.3 Interfaces

A means to collect the update SID, STAR, runway in use, and to distribute to AO, would be required.

### 6.8.3 ATM2000+ Timescale

This application is proposed for implementation in the short term (from around 2000–2002), within the [ATM2000+] initiatives on enhancement of data sharing.
6.8.4 Evaluation of Costs and Benefits

6.8.4.1 Areas of Cost and Benefit
The first source of benefit is the reduction of the fuel to be loaded, allowing a cheaper flight cost.

The second source of benefits is the improvement of the knowledge on the planned flights, on 4D-FPL and ETA. This would enable other applications, for example: applications on Departures Management (sections 8.2, 8.3, 8.4), In-Flight Traffic Management (section 7.2), Integrated Arrival and Departure Management (section 7.5).

The additional costs may come from:
- the communication costs (connections, data transfer);
- the dedicated systems (if any) for preparing, sending, receiving and translating the data;
- the corresponding additional staff needed either to update the data or retrieve it;
- the required modification in existing operational software for efficient use of new data.

6.8.4.2 Metrics
Possible metrics are:
1. Number of airports and aircraft operators participating actively.
2. Reduction of loaded fuel, for individual flights and for the overall fleet.
3. Improved accuracy and/or reliability of estimate of ETA being used by a given actor before take-off. Compare estimates in the current system and in the proposed improved system.
4. If FPL updates are used to improve load predictions in Tactical ATFM - reliability/accuracy of CFMU load of sector calculation.
5. For what number of days a year the weather forecast is stable enough for reasonable confidence in STAR forecast.
6. Additional costs due to communications and data management by each actor involved.

6.8.5 Dependencies
Weather forecast at airports are required together with the corresponding planning of configuration changes. This aspect is not really different from today. Nevertheless, access to and the of weather data could be treated independently, as in the present organisation, or in a co-ordinated manner.

Strong dependencies exist also with other applications which use and/or exchange the same data as this application. The same communication means may therefore be considered to transmit the following data:
- estimation and provision of flight plan data as in the application Distribution of AO/Aircraft Flight Plan Information (section 7.1),
- estimation of Off-Block Time (EOBT), Take-Off Time (ETD) as in the applications on Departures Management (sections 8.2, 8.3, 8.4),
- estimation of time of arrival (ETA) as in In-Flight Traffic Management (section 7.2) and in the applications on Arrivals Management (sections 7.3 and 7.4).
On-going projects such as ARAMIS (arrival management), MANTEA (surface management), DA-VINCI (integrated arrival and departure management), 4-MIDABLE (4D trajectory planning, using weather data, for improved control of approach) may be considered as inputs for improvement of identification of dependencies with existing systems and for feasibility analysis.

6.8.6 Problems and Further Studies Required

1. Identification of the flights concerned: short haul only, or up to long haul flight to European airports?

2. Optimisation of the time to send the data, taking into account the weather forecast reliability and the user needs.


4. As an aircraft will take less contingency fuel on a regular basis, controllers may not be able to hold them in the stacks as long as before. A cost/benefit analysis of the trade-off between fuel saving and disruption created by an increased number of “short fuel” flights must be made to determine whether this application is worth implementing in practice.

5. How much improvement in predictability of en-route and arrival traffic would be obtained?

6. Further benefits that would be obtained in linking this application with Arrival Management (sections 7.3 and 7.4) and with Collaborative Stand Allocation (section 8.1). This would probably need to be studied for each airport. The connection with Arrival Management would allow to take into account the expected holding time in approach.

7. Costs of communication, taking into account the amount of data flows.
7. EN-ROUTE AND TERMINAL AIR TRAFFIC CONTROL

Seven potential applications of CDM have been identified within the [ATM2000+] core process of En-Route and Terminal Air Traffic Control. They are described in sections 7.1 to 7.7:

- **Distribution of AO/Aircraft Flight Plan Information.** Aircraft operators and aircraft have better information than ATC concerning the intentions of a flight, while ATC has better information on the constraints. A possible collaborative application focused on improved information exchange is to develop the communications necessary to send flight plan and trajectory-related information, along with updates on departure time, to ATC.

- **In-Flight Traffic Management.** The objective of a CDM application for In-Flight Traffic Management (IFTM) is to allow AOCs and Airports to participate in and contribute to planning in the airborne, en-route phase of flight according to their knowledge and their interest. Benefits will be achievable for individual flights, as well as improvement of the traffic organisation. AOs will be able to modify flight plans at a stage where significant cost savings may be achievable. The ATS provider will gain knowledge of the users' interests, providing a better service by taking these into account in the medium-term planning process. AAs and airport ATC will gain access to the planning process when this might be relevant, given the landing conditions, landing rates and possibly, a preferred landing sequence.

- **Arrivals Management 1: Estimation of In-Block Time.** This application aims at providing Airport Authorities at busy airports with an accurate estimate of a flight's in-block time sooner than it is available now, so that they can better organise the stand allocation. In order to do this, the flight's expected stack exit time will need to be made available as soon as possible, and combined with estimated taxi time.

- **Arrivals Management 2: Optimisation of Arrivals.** The objective is to involve the Aircraft Operator and/or the Airport Authority in the arrivals planning process where possible. The first part of this is that either actor may request prioritisation, taking into account his own priorities for example on “rotation” operations, on passenger transfer problems or on the availability of airport resources. The second part is to enable AOs to make better decisions for example about diversions, by ensuring they are informed about planning conditions for the arrival traffic as early and as accurately as possible.

- **Integrated Arrivals and Departures Management.** The aim is to alleviate congestion problems if several airports experience arrival and possibly also departure capacity problems. It is expected that coupling these planning processes may result in better use of airports' capacity, and that this approach may contribute to achieving the planning of scheduled air traffic as close as possible to their scheduled departure and arrival times. Collaboration between airports on integrated planning is guided by a prioritisation mechanism, and arrivals planning at a congested airport will result in assigning priority to ensure the imposed constraints are met. Potential flexibility of departure planning is used to serve arrival planning where resources to accommodate arrivals are scarce.

- **Autonomous Separation in Free Flight Airspace.** Free Flight airspace is an important element of the proposed operational concept defined in the EATMS OCD. Aspects include the Airspace Management task of providing Free Flight airspace and the ATC tasks of implementing delegation of separation assurance or free manoeuvring.

- **Meteo Information Exchange.** This application concerns the distribution and sharing of meteorological information in order to improve users’ ability to take into account the impact of meteorological conditions. This includes distribution of pilot reports (especially of severe weather), wind and temperature updates from on-board sensors and meteorological service providers’ products (both existing and foreseen).
7.1 Distribution of AO/Aircraft Flight Plan Information

7.1.1 Context
It is well established that aircraft operators and aircraft have better information than ATC concerning the intentions of a flight. ATC, in contrast, has better information on the constraints.

7.1.2 Description
A possible collaborative application focused on improved information exchange is to develop the communications necessary to send flight plan and trajectory-related information, along with updates on departure time, to ATC. This could be particularly useful in the thirty minutes or so coming up to push-back when information on factors that are necessary for trajectory prediction (such as takeoff weight) are known accurately. (Of course, provision of this information does not overcome the issue of pilots deviating from FMS-entered plans in-flight, another significant barrier to reliable ground-based trajectory prediction).

A second example of where this would be particularly useful is in providing European ACCs with flight plan information and updated estimated times of arrival for eastbound north Atlantic traffic. This could be supplied either by individual AOCs, or alternatively by the Oceanic Control Units.

This application falls within the Initial and Enhanced Automation of Planning Tasks [ATM2000+], and is proposed for implementation in the medium term, perhaps between 2003 and 2007.
7.2 In-Flight Traffic Management

7.2.1 General Description

7.2.1.1 Context
In-Flight Traffic Management (IFTM) for Collaborative Decision Making covers a wide range of possible future applications. IFTM concerns planning activities with a medium-term timeframe. These planning activities exceed the planning horizon of the Planning Controller (PC), and are complementary to the planning of the PC. Therefore, these planning activities have to be accomplished at least 10 minutes before the aircraft enters the sector, and the scope includes planning over several sectors. IFTM planning is constrained by the information available for the planning and its quality. For example, uncertainty over departure times of flights places constraints on the accuracy of decision making, while in the longer term improved trajectory prediction may facilitate ATC planning up to 40 minutes ahead [PD/3-OSD].

The domain of IFTM, as defined here, may be divided into several parts, for example:

1. IFTM triggered by flow management requirements: it could be speed control or rerouting for long haul flights, aiming to alleviate the sector load during peak hours;
2. IFTM triggered by ATC: it could be aimed to deconflict or to decomplexify the traffic, e.g. via multi sector planning as it is described in PHARE PD/3 [PD/3-OSD], but also to meet arrival times as requested by an arrival manager at the destination airport;
3. IFTM triggered by the AO: aimed at reaching internal goals such as an arrival window in the frame of hub operations or an optimization of the flight path as en-route wind information becomes available;
4. IFTM triggered by external constraints such as activation of a military area or occurrence of severe weather: this part may be integrated with items 2 or 3.

This chapter focuses on IFTM for en-route ATC only. Short term ideas reflect developments of today's systems while longer term ideas make allowance for PHARE concepts such as Multi-Sector Planning. Other IFTM-related applications, i.e. related to arrival management, are dealt with in sections 7.3 and 7.4.

Re-planning a flight during the en-route airborne phases of flight can be required due to incidental events, forcing a change, or it can be desirable for flight performance or other reasons of efficiency or economy. Reasons for re-planning include:

- To optimise towards optimal flight scheduling: Delay related problems might suggest to re-plan the flight.
- To avoid congestion: Traffic congestion at arrival and/or at downstream sectors may suggest to look for less constrained flight paths, and a planning that avoids holding manoeuvres.
- Free routing options: Available airspace might suggest to select a more direct route, e.g. via Conditional Routes (CDR3s).
- Arrival capacity at the destination airport: Slot availability might be a motive to adapt the planning.
- To avoid unfavourable weather conditions: Received weather information might suggest to look for more optimal flight paths.
- At pilot’s request: The pilot may have other reasons to ask to change the flight plan for his flight and to adapt the planning accordingly.
A CDM application for en-route IFTM may be developed on an evolutionary way, and two stages are discussed below.

A short-term implementation could be associated with a “super-sector” PC, tasked to perform limited planning tasks such as early co-ordination with military ATC for shared use of airspace, planning a flight’s crossing of multiple sectors within an FIR, and re-planning a flight in response to requests submitted by AOCs.

In the longer term with the availability of full 4D-negotiation this might be developed to a concept of Multi-Sector Planning with an active planning role as described in [PD/3-OSD], supplemented by new co-ordination tasks related to advanced implementation of ASM.

7.2.1.2 Objectives and Benefits

The objective of this IFTM application is to allow all possible parties to contribute according to their interest and their capabilities to the decision making process in the airborne, en-route phases of flight. Parties with an interest to participate in medium-term flight planning are the Airline Operators (AOs), and, in some particular cases, the Airports (AAs), and airport ATC units.

Increased flexibility of use airspace, free routing and better predictability of the performance of the flight will make it beneficial to anticipate at an early stage an optimal flight performance. Benefits will be achievable for individual flights, as well as for options to improve traffic organisation. En-route traffic organisation is a task for ATC. However, the active participation of AOs, and possibly other actors, is required in order to be able to select the optimal planning for individual flights. It is expected therefore that en-route IFTM will be more effective when it includes collaborative decision making features.

Because a full implementation of this IFTM concept requires a fairly long process of development and implementation, a short-term implementation is proposed as a first step of an evolutionary development. Where shared use of (military) airspace allows ATC to opt for co-ordination with military ATC on the most efficient routing of their flights, AOs are enabled to submit requests to make use of this extra capacity.

The expected benefits of IFTM are:

- for the ATS provider: knowledge of the users’ interests which, when taken into account in the process of medium-term planning, improves the quality of services provided;
- for AOs: to be able to modify flight plans at a stage where significant cost savings may be achievable under appropriate conditions;
- for AAs and airport ATC: to have access to the planning process when this might be relevant, given the landing conditions, landing rates and possibly a preferred landing sequence.

7.2.1.3 Collaborative Decision Making Aspects

Specifically in the en-route flight phase, there are opportunities to optimise the flight planning. ATC is tasked to perform a planning process that supports safe, orderly and expeditious control. However, ATC is not in a position to take into account all aspects contributing to an optimal planning, because:

- ATC is not tasked to achieve optimisation of the performance of individual flights.
- ATC has insufficient knowledge of what is optimal for individual flights, and this concerns the circumstantial conditions, as well as the individual flight performance conditions.
- ATC, planning in en-route airspace, has no, or very limited, knowledge of arrival conditions, and how to deal with imposed restrictions.
Therefore, other parties (external to ATC) are more appropriate to initiate flight optimisation. The need to optimise a flight comes from the commercial interest of the Airline Operators (AOs). Another reason may be to optimise towards optimal arrival scheduling, which is an Airport ATC's interest.

The result of a CDM In-Flight Traffic Management application will be that ATC might be able to accept individual flight plan changes on request of AOs and Airport ATCs. For reasons of fairness and transparency, these requests will have to be honoured on a first-come, first-served basis. At the other side, instantaneous information distribution to all interested parties is mandatory, because adequate information provision is the key to the required knowledge.

ATC has to ensure a safe, organised and efficient flow of traffic. Therefore, proposed flight plan changes are subject to a judgement of ATC. ATC has to be authorised to accept, to amend and to refuse proposed changes. In this way, this application aims to achieve an improvement on the overall efficiency and effectiveness of ATM, as well as an improvement of the efficiency of the individual operations of the Airline Operators, achieved in an open and transparent way.

### 7.2.2 Description of Process

#### 7.2.2.1 Actors

Several actors could potentially be actively involved in In-Flight Traffic Management. These are:

- ATC;
- AOs;
- AAs;
- the pilot, who will participate in AOs re-planning activities;
- weather services, providing accurate weather now-casts and forecasts;
- military control centres, imposing or removing flight restrictions in airspace required for their operations;
- the CFMU, providing ATFM and ASM services.

AOCs aim to perform their flights in the most efficient and economical way based on their operating schedule. The AOC will be able to make and to prepare flight change proposals if the AOC has sufficient knowledge of the actual conditions of ATC planning and control.

Once the flight is airborne, the interest of AOs, enabling them to modify a flight plan, is served most optimally in the en-route flight phase, because of the potential opportunities to take decisions with a medium to long term impact on the performance of the flight. The ATCO, planning with an IFTM scope, is in a good position to be tasked to perform the co-ordination with AOs. He is able to support flight plan changes with the required scope of control, and he is able to supply the required information to AOs.

The pilot is not necessarily directly involved in a medium-term flight re-planning process. The pilot's primary concern during the flight is to accomplish tactical flight operations. However, the pilot will co-ordinate with AOC (e.g. via a datalink such as ACARS), which should be in a position to combine the pilot's interest with information concerning questions like changing weather conditions, capacity at destination, local airspace congestion, ATC planning, and its own scheduling and planning interests. AOC may derive from the combined knowledge a proposal for re-planning to ATC.
Potential Applications of Collaborative Decision Making

In the context of the implementation of advanced 4D and datalink concepts, 4D capability might allow the pilot to extend his view and to perform flight planning with an extended scope. This might allow him to communicate this information directly with ATC [PD/3-OSD] as well as the AOC.

7.2.2.2 Information Flows and Processes

The short-term implementation of IFTM will adhere to the functioning of a present-day co-ordinator between sectors within a centre (or FIR) and/or between a civil and a military centre. An example of the information flows and processes is given in figure 7-1.

A possible present-day multi-sector planning task within a centre will consist of making estimates for entry, exit and sector transit times, as well as estimates for entry, exit and transition levels. A possible co-ordinating task with military authorities will consist of reaching agreement for an individual flight for use of a planned route through military airspace. The military authorities will ensure separation of their flights from the co-ordinated flight, whilst both civil and military authorities will be enabled to monitor the progress of the co-ordinated flight.

In a CDM environment, the AOCs will also be informed of surveillance and planning information, including en-route and arrival demand and capacity. With this information AOCs should be capable to request en-route to, for example, have their aircraft re-routed to avoid areas of observed severe weather or to minimise holding. Ultimately at least 10 minutes before the flight enters the area, AOC should be able to propose a flight plan change, which
may comprise level changes, parallel routing, direct routing, and possibly also a routing through military airspace (assuming an airspace status which allows this).

The Airport ATC (APP), planning the arrivals sequencing, will receive similar en-route planning information, allowing them to make an early assessment of planning the expected arrival flow. If there is a need to adapt the runway configuration and/or the runway arrival rates, the Airport ATC will be able to take appropriate decisions, monitoring the expected arrival flows. The Airport ATC units may co-ordinate with the IFTM ATCO.

AAs may take an initiative when the availability of stands might induce prioritisation of arrival sequences. This may have an impact on en-route flight planning also.

If the pilot needs a flight plan change within the scope of a short-term implementation of IFTM, he will inform the AOC, using for example ACARS communication (the network available today), and AOC might take the initiative to make a proposal.

In a longer-term implementation, the process of co-ordination between ATC, AOC and Airport ATC takes place in the context of a multi-sector planner (MSP) implementation [PD/3-OSD]. This implies significantly refined planning, compared to today’s planning, making use of 4D trajectory prediction on the ground, and 4D prediction and guidance capability of the aircraft. All aircraft are assumed to be equipped with RNAV capability, and part of the fleet will be 4D equipped. The accurate, trajectory-based planning needs to be supported by an ATN for data exchange, satisfying the need for high-capacity, reliable, consistent, digital datalink exchange.

The role of MSP planning has a more elaborate scope than for the same CDM application based on a present-day scenario, since it implies an extension from a mainly co-ordinating task to an active planning process in an early stage of medium-term ATC planning. The MSP will be able to solve congestion problems, performing a flow management task, by re-planning individual flights.

### 7.2.2.3 Interfaces

The short-term implementation makes use as much as possible of currently-available systems, as well as of currently-available information (surveillance and flight plan information), whilst the long-term implementation expects more advanced implementations to be available, more in line with an evolution towards an EATMS.

For the short-term application of IFTM, tactical communication is voice based, supported by distributed planning and surveillance information. Typically co-ordination agreements are reached by telephone and/or electronic data exchanges and clearances are submitted via R/T. Between pilot and AOC, ACARS is available, as at present (see figure 7-2).
A long-term IFTM application is based on communication supported by an ATN, and the exchange of detailed planning information based on trajectories. Voice communication is available mainly for exception handling. A transparent implementation of layered planning requires distribution of CFMU data to ATC centres, to be used to start ATC planning, and distribution of planning results from centres to AOCs, etc.. Also, aircraft/ATC communication will make use of the capabilities to exchange planned trajectories via the ATN (see figure 7-3).
7.2.3 ATM2000+ Timescale

In-Flight Traffic Management is part of the redistribution of control tasks, as foreseen by the ATM2000+ strategy plan [ATM2000+]. As a potential extension to present-day practices, this concept can be implemented in the relatively short term (around 2003). In the context of a more ambitious implementation, this concept should be considered as a long-term development, as part of the implementation of a layered planning concept, including Multi-Sector Planning, filling the gap between CFMU pre-departure planning and ATC. The associated timeframe is from 2010 onwards.

7.2.4 Evaluation of Costs and Benefits

7.2.4.1 Areas of Cost and Benefit

Airline Operators are expected to benefit by optimising their operations to respond to traffic density, the airspace environment and weather.

Secondly, Airport Authorities may benefit from IFTM in anticipation on handling arrival flows. Airport ATC can have an early view of expected arrival traffic, and can decide on the runway configuration in use, and the most appropriate moment to change the configuration.

The other side of the coin is an expected increase of workload for ATC. More co-ordination is necessary to respond to requests of AOs, Airport ATC and AAs. In the short term this will imply more co-ordination for existing planning controller (PC) positions. In the longer term the Multi-Sector Planner, initially envisaged to alleviate the work of planning controllers, can perform these tasks.
7.2.4.2 Metrics
The major indicators of benefits expected from IFTM are a possible appraisal by AOs and Airport ATC units, and positive effects on the performance of the concerned flights. Other indicators are related to measurable improvements of the process of ATC, and in particular, possible effects on arrival management for destination airports.

Benefits for AOs, and positive effects on the performance of flights are expected from:
- measuring direct benefits in cost and time, and estimating indirect benefits as e.g. acceptance of preferred sequencing;
- timely response on delays;
- timely response on changed weather conditions;
- timely response on exception handling conditions, e.g. diverting a flight.

Benefits for Airport ATC and AAs are expected from:
- the ability to react on changing landing conditions.

The effects on ATC are more complex, and may be positive as well as negative. Effects on ATC planning and control may be related to:
- effects on traffic organisation, in which sense options for use of free-routing are being applied and in which sense they might contribute to the complexity of ATC;
- effects on efficient use of the dynamics of the availability of airspace;
- effects on arrivals management and an analysis of the efficiency of the use of the runway(s) of concerned airports as result of en-route flight plan changes;
- effects on the efficiency of ground movements and efficient use of airport resources.

Finally, workload costs will arise from this application of CDM. Co-ordination, communication, monitoring, making proposals and counter proposals, and accepting them will cost effort, and the workload of all parties involved, associated with this work, is an important measurable cost factor.

7.2.5 Dependencies
The application to support CDM during the In-Flight Traffic Management process is based on the assumption that the interest of AOCs, Airport ATC and AAs to affect the planning is mainly focused on decisions with a medium to long-term impact on the performance of the flight, and that this interest is served best in an en-route flight phase, in an early stage, with a wide geographical scope.

The AOs will consider a flight from its current position to arrival. They should be able to select the airspace of interest for that flight and to be able to judge the opportunities to re-plan the flight. Therefore, information provision be through an ASD-like presentation, comprising:
- presentation of the current status of airspace, allowing users to visualise the opportunities for direct routing;
- presentation of traffic flow information, allowing users to visualise the flows of traffic and the traffic densities in space and time;
- an option to filter flow information in 4D, e.g. to apply height and/or time filters;
- presentation of available capacity in space and time;
• display of detailed flight plan information, concerning an AO’s own flights, and enabling the AOC to create proposals (“what-if” functionality);
• the optional presentation of available weather now-casts and/or forecasts.

Implicitly, there is an extra requirement to support a uniform and transparent view of the airspace and the traffic situation over a large area. Also it should be possible to identify the ATCO in charge of planning each area. Updates on flow and traffic density information must be distributed, as well as all updates on flight plan information of own flights. This implies the requirement to support access for AOCs and AAs to a harmonised distributed database, containing in-flight planning information of European ATC centres.

The AOs should be able to select a flight, to assess the planned trajectory of that flight against capacity constraints, and to send a planning proposal to the applicable controlling centre. This implies a requirement to support interactive planning and co-ordination functionality tailored to the AOC’s needs.

The interest of Airport ATC is such that only specific information of en-route traffic is required, since their interest concerns arrival flows. Airport ATC might wish to adapt en-route planning in order to be able to adapt the arrival sequence order and/or the arrival landing rates.

7.2.6 Problems and Further Studies Required

Studying the In-Flight Traffic Management concept deserves a split into short-term and long-term R&D effort; the short-term R&D based on extending present-day practices, the longer-term R&D on studying the features of a layered planning concept.

The shorter-term R&D should focus on pre-operational trials, to be exercised in an operational context. The additional effort required for CDM can be provided by existing PCs or by a new controller, co-ordinating between the PCs and AOCs and/or Airport ATC units. Research is required to see if and how collaborative decision making may influence the work/workload of existing controllers.

The longer-term R&D may consider the MSP concept, the 4D air-ground integration and 4D planning concept [PD/3-OSD] as a reference, extended with features for CDM.

In the context of longer-term R&D, the extended planning by an MSP, reaching up to 40 minutes prediction time, requires highly accurate and reliable trajectory prediction capability. Prediction accuracy and reliability depends on an accurate aircraft model, accurate aircraft type modelling data, and accurate weather data. Moreover, the prediction should be consistent between the different centres and aircraft making the predictions. Finally, the predictions become more relevant if they are known and/or made by the aircraft’s FMS, and used by the aircraft to perform 4D guidance. Therefore, a good and reliable exchange procedure of 4D flight information between air and ground is mandatory for optimal benefits of this extended planning process. Tools development is a requirement, and the integrity of data exchange procedures should also be investigated.
7.3 Arrivals Management 1: Estimation of In-Block Time

7.3.1 General Description

7.3.1.1 Context

Many TMAs of European airports place arriving aircraft in holding stacks at certain times, when the demand is exceedingly high. With holding stacks, controllers can send a continuous flow of aircraft while sequencing them according to their time of arrival into the stack, and their vortex category, so as to fit the maximum number of aircraft into the minimum amount of time. Thus the use of the runway is optimised.

The arrival sequence up to the gate/stand is described on the following time scale:

- time of entry in TMA (TET)
- (transfer from ACC to APP)
- time of entry in stack (TES)
- time of exit of stack (TXS)
- time of transfer from APP to TWR
- time over outer marker (TOM)
- time of arrival (touch down) (TA)
- time in-block (IBT)

\[ Figure \ 7-4: \ Arrival \ sequence \]

Interviews with users [FASTER], showed that most airport authorities are updated by ATC on the time of arrival when:

- the aircraft leaves the stack (TXS),
- and/or
- the aircraft is passing the outer marker (TOM).

Airport authorities know by experience the taxi time from the runway to the gate/stand. They know roughly how much time it takes for the aircraft to arrive at the gate/stand once it is out of the stack. This leaves them no time to adjust the stand allocation if necessary.

For example, if the allocated gate/stand is not freed for the arriving aircraft at TXS, finding another gate/stand is impossible if the airport is congested. Moreover, one should keep in mind that an arriving aircraft is also a departing aircraft: its next departing passengers have been directed to the boarding hall corresponding to the original allocated gate/stand, long before TXS. Therefore, the arriving aircraft must wait on the tarmac for the other to leave. Had they known earlier the Estimated In-Block Time, the Airport Authority could have
prioritised operations on the departing aircraft so it could have freed the gate/stand on time, or organised reception of the arriving aircraft on a parking area with the corresponding transport of departing passengers and so forth.

Airport authorities want to be informed earlier of the TA, thereby of the IBT. They want to be updated on the time of arrival more in advance than at TXS, preferably when the aircraft enters the stack.

Airlines operators are also interested in receiving these data in advance, to better organise their turn-arounds.

In the long term, due to increasing congestion on the ground, airports will less and less be able to rely on their experience to estimate early the required taxi time. They will need to rely on the ground controllers to get early estimation of this value which along with ETA helps to determine the Estimated In Block Time.

### 7.3.1.2 Objectives and Benefits

Given this situation, the objective of the proposed application is to inform the airlines and the stand allocation units of:

- the arrival of an aircraft in the stack,
- the waiting time of the aircraft in the stack,
- the exit of the aircraft from the stack,
- the taxi time to the stand.

The expected benefits of providing this information to the airport authority and AOCs, are:

- an improvement of the stand allocation process, due to the earlier availability of reliable and accurate information,
- a better utilisation of the ground facilities,
- improved operations for airlines,
- a shared understanding of the ETA parameter, which would then be common to all the actors, representing an essential enabling step towards collaborative decision making.

### 7.3.1.3 Collaborative Decision Making Aspects

In order to improve the accuracy of the expected time at gate/stand, five entities are required to communicate:

- the APP ATC, which manages the arrival sequencing of the aircraft, through the use of holding stacks,
- the Tower ATC, which controls landings on runways,
- the ground controller, which oversees the movement of aircraft on the taxiways and aprons,
- the airport authority including here the stand allocation unit, handlers, apron services..., 
- the airlines operation centres, which manage the ground operations for the company.

The information required by the last two entities are in most cases available to the three former ones, and so their collaboration is needed to improve the performance of the whole process.
7.3.2 Description of Process

7.3.2.1 Actors

**APP ATC** is responsible for controlling arriving aircraft and for sequencing them out of the stacks. Currently, Tower ATC is usually informed when a flight leaves a stack.

The proposed process is for APP ATC to inform Tower ATC of the estimated stack exit time (ETXS) as soon as it is known, and not just after it has happens. The process could be improved if the APP ATC gave the Tower ATC an estimate of the time of the exit of stack as soon as the aircraft enters the stack.

**Tower ATC** is in charge of controlling the aircraft as they land. The Tower ATC usually takes control of the flight when it is established on final (around 7 miles from the airport for Heathrow).

This actor is the best placed to update on the estimated time of arrival (ETA) as soon as it knows the Estimated Time of Exit of the Stack (ETXS).

**Ground Control** is in charge of guiding the aircraft from the runway to its allocated gate/stand. This actor is best placed to evaluate the required taxi-time to the gate/stand. In the long term, the use of A-SMGCS will help better estimate these taxi-times.

**Airport Authority:** The proposed application focuses on both the stand allocation unit and the handlers, whose task is to assign a stand to each arriving aircraft, according to aircraft type, airline, landing airway, and to prepare the aircraft for its next flight.

Currently, to do so, they can base their actions on the following data:

- FPLs,
- CFMU slots (not always available to them)
- actual exit from the holding stack
- actual time over first marker.

The proposed process consists in adding two extra data items (expected time of stack exit, provided earlier than the actual one, expected taxi time), to improve the allocation process and the organisation of the turn-arounds.

**AOC:** The expected time at gate/stand is a very important information for the airline, since it has an impact on several factors:

- expected departure time of the next flight using the arriving aircraft,
- expected delay of the passengers, in the case of correspondence between flights,
- expected delay of personnel who are in the incoming flight...

Therefore a more accurate and earlier knowledge of this information might have beneficial effects for the airlines.
7.3.2.2 Information Flows and Processes

Information flow:

Figure 7-5: Interactions between actors in the distribution of EIBT
7.3.2.3 Interfaces

**Expected time of Exit of the Stack (ETXS):** This message contains the flight call-sign, the arrival airport name and the expected time at which the flight will leave the stack to begin its final approach. It is sent when the aircraft enters the stack.

**Estimated Time of Arrival:** This message contains the flight call-sign, the arrival airport name and the expected time of arrival (ETA) based on the ETXS.

**Expected In-Block Time:** This message contains the flight call-sign, the arrival airport name and the updated time of arrival at the stand (EIBT).

7.3.3 ATM2000+ Timescale

This application is proposed as a near term part of the Automated Arrivals Management area of system improvement [ATM2000+]. That document indicates that FDPS interoperability can be expected before 2005. Initial implementation of this application should be possible by 2000-2002.
7.3.4 Evaluation of Costs and Benefits

7.3.4.1 Areas of Cost and Benefit

Airlines, stand allocation units and handlers should be the beneficiaries of the early delivery of expected stack exit time, and expected taxi-time. These supplementary data should enable them to better anticipate the aircraft arrivals, and to reach higher efficiency in their operations.

However, benefits could be reaped by the Tower ATC from the availability of accurate ETA, taking into account waiting times data. Such data may help the co-ordination of arrival and departure for improvement of use of runways.

The costs are linked to the installation and use of different communication means which will be required to communicate the data from the ATC entities to the airport authorities and AOCs.

This use may also generate some additional workload (at least for the transmitting side, since on the receiving side the concept is aimed at improving the efficiency of the process, which could alleviate the current workload). This could bring the need of supplementary manpower, with the associated costs.

7.3.4.2 Metrics

As indicated above, the new information exchanges could translate into reduced turn-around times, and reduced delays for the airlines.

The indicators of success for the stand allocation unit will concern the workload generated by the tactical stand allocation task, and the efficiency of the process (number of situations where the optimal solution could not be found because of a lack of timely and accurate information).

From handlers point of view, the efficiency of the allocation of resources for the flights may be considered as indicator of success.

7.3.5 Dependencies

This application is closely related to existing work on A-SMGCS.

7.3.6 Problems and Further Studies Required

The arrival/landing sequences are organised by mixing aircraft belonging to different vortex categories according to a certain order so as to maximise the airport capacity.

This implies that aircraft do not necessarily leave the stack(s) in the same order as they entered it (first in / first out), and therefore the exit time is not always known when the aircraft flies into the stack(s). This is especially true when several stacks are used at one airport.

Moreover, the APP ATC may anticipate the arrival of the different aircraft in the stack(s).

A similar problem exists for taxi-time assessment. In this case, it will be necessary to determine whether this data is presently accurately evaluated, and if so, with which tools, and from which data. This aspect is linked with the development of A-SMGCS which may consider the ground congestion in taxi-time assessment and forecast.

Thus studies will be needed to:

• to determine if, when and where the different pieces of information (arrival of the aircraft in the stack, waiting time in the stack, exit of the aircraft from the stack, taxi time) are currently available,
• to define the time limits of the process i.e. assessing the time at which the information
should be produced.

Second it will be necessary to analyse the different means that could be used to spread
them to the different categories of people who would need it, and to determine the
associated costs and constraints.

Third, one will have to assess the impact of the availability of these data to the Airport
Authorities and to the Airline Operations Centres on their efficiency.

Another problem will be the translation of the benefits brought by the new collaboration into
financial terms.

This requires:
• to quantify the benefits (reduction of turn-around times or delays for example). This point
  may require the use of airports simulations.
• to translate the operational metrics into financial ones.

Furthermore, the organisation of airport and ATC operations widely differs according to the
different airports: location of APP and Tower ATC, entities responsible for the different
activities, .... Typical cases will so have to be selected, and further investigated.
7.4 Arrivals Management 2: Optimisation of Arrivals

7.4.1 General Description

7.4.1.1 Context

Arrivals Management is essentially a tightly coupled process between arrivals ATC and the aircraft. Given the highly tactical nature of the process, and the very well known objective (optimal use of available capacity), there are only limited opportunities where involvement of other parties in this process might be beneficial.

In current operational practice, Arrivals Management consists of a purely tactical process of acceptance of flights entering the TMA, and, if applicable, leaving a holding stack area, and performing an initial and final approach. The focus is on maintaining the separation and optimal use of the available capacity. It is not foreseen that possible improvements in this phase of flight might concern a role for AO or airport.

The main shortfalls of the current system are concerning the problems to make use of the available capacity during peak periods, in particular if the peak period has a long duration and the capability to apply Continuous Descent Approaches (CDAs), required by noise abatement regulation. The strategy to solve these problems stems from extending the planning horizon, and enforcing the coupling between air and ground (4D arrival procedures). Also this process contributes to reducing the possibilities for collaborative decision making.

It is realistic to restrict possible applications for collaborative decision making to the area of solving disruptions mainly, i.e. in case of stack operations, causing significant delays. The following cases can be identified:

- preparing early ATC strategic decisions on most efficient and economical arrival planning (see also In-Flight Traffic Management application, in section 7.2);
- prioritisation of the order of aircraft leave holding patterns, possibly also taking into account stand availability;
- taking decisions on diverting a flight;
- collaboration in decision-making on changes to the runway configuration in use;
- indicating preferred landing runway.

7.4.1.2 Objectives and Benefits

The objective of the CDM application for arrival management is to be able to react adequately if, in case of a change to the arrival capacity, the arrival sequence has to be re-planned and it is possible to take into account third parties’ interests.

In case of temporary shortfall of arrival capacity, aircraft will often be placed in holding manoeuvres. It might be feasible to organise the order in which aircraft are released from holding in a more optimal fashion, if instead of a simple first-come, first-serve principle, user preferences can be taken into account. Barring safety issues, it may be in the interest of the AOC or airport to opt for another sequence, to better manage and allocate resources.

Another option, if holding manoeuvres are imposed, is to opt for diverting. Currently it is the pilot/AOC who takes the initiative for diversions, with little involvement of ATC and Airports. It is however in the interest of AOC to have good information on the conditions, and to be able to take the appropriate decisions. Through this CDM application ATC and Airports can
supply improved information for decision-making on diversions, such as weather and available parking space at alternate airports.

The benefits of adding collaborative decision making options to Arrival Management may be to enable AOCs and the AA to find acceptable solutions in situations of reduced arrival capacity or situations of an overload of demand, due to unforeseen external conditions. This can be beneficial in particular to minimise non-linear costs (e.g. missed connections) as result of delays, and to improve system recovery from disruption.

### 7.4.1.3 Collaborative Decision Making Aspects

The responsibility of ATC is to provide instructions to guide each flight safely and efficiently to the runway. There is no justification to deviate from a first-come first-served order unless for safety and efficiency reasons. The objective should be to honour individual requests and, at the same time, to reach a balanced and fair optimum of handling arrival traffic demand, applying some kind of request assignment regulation scheme.

Any prioritisation must be transparent and follow agreed rules. A request of prioritisation might be honoured, for example in the following cases:

- “banking” is applicable, the concerned flight is part of a group of arriving flights of the same operator, and of clear interest as part of a “hub” operation;
- the flight is coupled to a “rotation” operation, which is critical (risk of serious delay, or risk of losing its departure slot);
- there is other evidence of interest due to the presence of transfer passengers with connecting flights;
- Airports possibly may collaborate to prioritize arrivals according to stand availability, at airports where stand capacity is a limiting factor.

It might be considered to limit changes in the sequence to flights from the same AO. In this case, there is no question of conflict of interest, but the applicability may be limited, and not all AOs will be able to profit from this approach.

### 7.4.2 Description of Process

#### 7.4.2.1 Actors

ATC, Airport Authorities, Airline Operators and aircraft are the main actors concerned.

The main role of Airport ATC and Airport Authorities is to propose airport, or more specific runway configuration changes, taking into account prevailing weather conditions and environmental constraints (e.g. noise abatement).

The AOs will require access to up-to-date estimated arrival planning, and planned holding manoeuvres.

Aircraft may have more detailed real-time information, which puts them in a position to issue requests specific to their flight. However, specifically during the arrival phase, these requests are often time critical and flight critical, leaving no time and opportunity to coordinate with AOC.

#### 7.4.2.2 Information Flows and Processes

Approach Control (APP) performs Arrivals Management, considering:

- available landing capacity:
Potential Applications of Collaborative Decision Making

- number of runways in use, runway configuration (dependent or independent runways) and applicable arrival regulations (depending on aircraft type and equipment, and separation rules);
- required capacity for departures (in case of shared use of capacity);
- preferential use of runways: related to distance to the gate, or related to weight category, or related to noise abatement regulation;
- the most efficient and economical way to distribute arrival traffic over the available arrival capacity;
- the arrival acceptance rate, derived from the total landing capacity;
- the planned order of arrival (predicted estimates).

This planning may be disrupted by incidental events on changing airport conditions. These events may be caused by, for example:
- changing weather conditions;
- changing traffic conditions (inbound peak changing to an outbound peak);
- operational events at the airport.

In all cases temporary or longer term reduced arrival capacity will require ATC to direct flights to stacks.

If flights are held in stack areas, it may be possible to release them following a certain prioritisation scheme, instead of the lowest aircraft first. A reason for prioritisation may be the approach guidance equipment in the aircraft. Cat. I, Cat. II and Cat. III are normally arranged in the stack in “random” order, but conditions may be such that only Cat. III aircraft can land. They could be given priority to leave the stack first.

Insertion of aircraft in a stack at a level planned according to the order to release them, could be examined as an option.

Figure 7-7: Example of Information Flow and Process for CDM Arrival Management application
Prioritisation of holding traffic would probably require tool support to help the controller decide whether to meet requests for priority.

The AOC should be enabled to judge the capacity/demand problems, and to make a request for priority.

### 7.4.2.3 Interfaces

A CDM application for Arrival Management has to support distribution of arrival sequencing and stack information. AAs should be able to monitor the planning of arrival traffic. AOCs should be able to notice estimated delays, and to propose priority in releasing flights from the stacks. A ground-ground datalink is required to support exchange of accurate planning information.

For this application to succeed, all actors will require ATC arrival management information including stack management information on their planning displays. Proposals could be made by telephone or later by electronic means (see figure 7-8).

![Figure 7-8: Interfacing for CDM Arrival Management application](image)

### 7.4.3 ATM2000+ Timescale

Arrival Management is part of the ATM Strategy for 2000+. A pre-operational AMAN (Arrival Manager) for ground-based arrival management, functioning in a European context, is under development [ATM2000+]. CDM options for Arrival Management can be added, based on the provision of stack planning information to interested parties. This application can be implemented in a medium-term time frame from around 2005.

The next stage of automation, Automated Arrival Management, is foreseen to be developed as part of "enhanced automation of planning tasks". Arrival management will be performed with support of 4D planning tools [ATM2000+]. CDM options associated with this level of
automation could be added based on the exchange of 4D planning information in a time frame from 2008 onwards.

### 7.4.4 Evaluation of Costs and Benefits

#### 7.4.4.1 Areas of Cost and Benefit

The main benefits related to Collaborative Decision Making in the Arrival Management process can be found in the area of reduction of rotation times (time between arrival and departure of a specific aircraft) and a better tuning of hub operations. Examples are:

- By choosing a landing runway close to the “reserved” gate, taxi time can be minimised. Consequently the aircraft can be ready earlier for the next flight.

- If obtaining a departure slot is a problem, priority could be given to keep the present slot. If the arriving flight is late, it may become a problem to make the slot. A solution to this problem could be to give the flight landing priority.

- Hub operations are even more dependent on an efficient landing schedule. Aircraft arrive and depart in “waves” and in the mean time passengers transfer from one flight to another. If an aircraft has a late arrival, its passengers may not be able to catch a connecting flight. To prevent this, priority may be given to a late arriving aircraft.

Airport Authorities can benefit from Collaborative Decision Making in the Arrival Management process by better anticipating the current and planned traffic situation and by being able to incorporate requests of ATC and AOC regarding e.g. runway configuration changes.

Costs to airspace users of prioritisation must be measured in order to ensure that an agreed equity policy is realised.

#### 7.4.4.2 Metrics

Metrics for Arrival Management are:

- change in controllers’ workload;
- change in overall delays.

Equity and transparency measures will be important for airspace users.

Prioritisation may affect the realisation of separated, stable traffic flows, and the impact of this on optimal use of the available capacity must be assessed.

### 7.4.5 Dependencies

There are links to other CDM applications:

- Arrival Management is tightly coupled to Departure Management at the same airport.

- In an early phase of Arrival Management the capacity can still be influenced by control on departures of short-haul flights via ATFM and Departure Management.

- This CDM application aims to find solutions for changing arrival conditions. If reduced arrival capacity is imminent for a longer period (e.g. more than half an hour), the problems of Arrival Management, dealing with reduced capacity, are part of a general strategy on disruption handling (see Disruption Recovery applications in sections 8.5 and 8.6). The longer the disruption endures, the more ATFM plays a role in balancing capacity and demand (see second bullet).
7.4.6 Problems and Further Studies Required
Development of a transparent and understandable priority regulation algorithm is an indispensable condition for acceptance of this application.
This algorithm should be assessed in an environment where different AOCs are able to select their preferences. This might require simulations on Arrival Management in which such partners could participate.
Participation of AOCs in decision making on Arrival Management is not necessarily related to the level of automation introduced in the ATM system. Therefore, AOCs’ participation might be investigated in different Arrival Management environments.
Owing to the dependency of Arrivals Management on human skills, real-time simulations will be required.

7.5 Integrated Arrivals and Departures Management

7.5.1 General Description

7.5.1.1 Context
Extended planning concepts will lead to an integration of different planning activities by a future, fully developed EATMS. In the extreme, the detailed planning of the departure, en-route and arrival phase of a flight are coupled, and therefore arrival planning at one airport is dependent on departing traffic on several other airports, as well as dependent on the en-route planning of long-haul flights.
Also coupling effects of departure and arrival planning at one airport may be expected when the available capacity is used close to its maximum extent. In case of shortfall of capacity, a balance is to be maintained between serving arrivals and departures, minimising overall delays.
In general, the more saturated resources are, the stronger will be the coupling effects on planning and control in all phases of flight.
Integrated departure and arrival planning will be most significant when:
• the usage of arrival capacity at destination is critical;
• the planning of departure traffic is critical (tight planning and saturation of use of available departure capacity, short turn-around times, complicated taxiing, and tight planning of use of ground facilities);
• en-route planning is complicated (high traffic density, closely allocated airports), and long-haul traffic is imposing its specific constraints.
The collaborative decision aspects become evident when the arrival capacity falls short at several airports situated at relatively short distances from each other (e.g. Paris, London, Brussels). Capacity shortfall may be caused by regular peak periods (as experienced by some core area hub airports) or caused by disruption (as discussed in section 8.6, Departures from Nearby Airfields). In both cases improved planning of departure sequencing can be coupled to a prioritisation scheme for airports on imposing arrival constraints.
It is proposed to develop a CDM application where improved information exchange amongst ATM service providers, Airports and AOCs will enable CFMU arrivals planning to be integrated seamlessly into Airport ATC’s arrival capacity planning, integrating airborne as well as pre-departure planning. Prioritisation, based on arrivals saturation, will modify the
departures planning in a way that is efficient in operations and as close as possible to optimal use of resources.

7.5.1.2 Objectives and Benefits
The integration of Arrivals and Departures Managers has two objectives:
• within one airport, co-optimising the sequences of arrivals and departures at that airport;
• between airports, so that the arrivals priorities at a flight’s destination airport are taken into account in the departures sequencing of its departure airport.

The objective of integration of the planning of these processes is to take into account the most severe arrival constraints as early as possible.

The benefits of such a planning strategy will be:
• economy of flights by a refinement of arrivals planning, such that short-haul departures avoid holding, or at least, the duration of holding manoeuvres is minimised;
• efficient use of scarce arrivals resources by using flexibility in departure planning at one or more airports;

Prioritisation would be applied in such a way organise air traffic as close as possible to the scheduled departure and arrival times.

7.5.1.3 Collaborative Decision Making Aspects
Arrivals Management will apply a systematic approach to managing the problems of lack of resources at saturated airports. Essentially, it involves collaborative planning in which the planning processes of the various actors (ATM, Airports, AOCs) will be coupled to each other to make best use of the available capacity and resources. Where necessary a prioritisation process will be applied to achieve optimisation.

7.5.2 Description of Process

7.5.2.1 Actors
Integration of arrivals and departures planning starts from tactical flow management, accomplished by CFMU, in collaboration with AOs. The arrival capacity planning and pre-departure planning is planned by planning controllers of the different Airport ATC Units. Imposed arrival constraints are input to revising the departure planning and, vice versa, the revised departure planning may change the arrival planning. En-route constraints, imposed by ACCs, might be an additional set of events to cause re-planning.
7.5.2.2 Information Flows and Processes

The integration of Arrivals and Departures Management assumes that advanced information exchange processes will be available for Arrivals Management and for Departures Management, as described in other related CDM applications in this report.

This application requires integration of a complex set of such planning information, requiring a strategy for process and data allocation. In outline this might include:

- AOCs and airports would provide ATC with continuously updated information on their current operational plans and constraints.
- The CFMU would provide and distribute planning data based on the best available trajectory predictions of flights in a pre-departure phase.
- The departure airport would provide detailed pre-departure planning based on trajectory prediction and taking into account AOC and airport planning constraints.
- The destination airport would provide arrival constraints based on arrival capacity planning which makes use of the best available trajectory predictions of arriving airborne and pre-departure traffic.
- The CFMU would re-plan tactically, based on the arrival and en-route constraints and available trajectory predictions. It would also assign priority indications to departure constraints.
• The departure airport would re-plan departures taking into account the updated
departure constraints.

Several significant improvements will be required to the current system in order that such an
integrated planning system can be fulfilled. Essential ones include:
• A very effective exchange of intent and planning data, with very fast and timely
exchange of accurate information. This is a significant hurdle in reaching the objective
from the current system.
• Any prioritisation should be assigned according to a set of accepted and transparent
rules, allowing verification by all parties.
• A balance may need to be found between imposing delays on long-haul flights and
short-haul flights.

7.5.2.3 Interfaces

The interfaces to be considered as relevant to the application for Integrated Arrivals and
Departures Management are interfaces supporting short-term pre-departure planning. The
actors for planning in this phase of flight, are transferred from the CFMU to the airports, at
departure as well as at destination.
The associated interfacing supports the exchange of trajectory based planning information and arrival constraints between Airport ATC and CFMU. Closely related planning activities require interfaces between local airports’ resource management and the airports’ ATC, and between the CFMU and AOCs.

7.5.3 ATM2000+ Timescale

Integrated Arrivals and Departures Management is identified [ATM2000+] as a long-term development. That document suggests that integration of Arrivals Management and Departures Management, together with airport surface management, en-route ATM, ATFM and AO processes will facilitate the transition to a full gate-to-gate management of flights by 2015.

7.5.4 Evaluation of Costs and Benefits

7.5.4.1 Areas of Cost and Benefit

Benefits are expected from a collaborative application of Integrated Arrivals and Departures Management for all operations at congested airports. Better control of arrival traffic by APP will save cost and will promote smooth handling of the traffic at those airports. AOs may profit from an efficient flight performance within the restrictions imposed by the available capacity.

The costs are imposed on those airports which have flights departing for congested destinations. Departure planning at those airports is required to be more flexible and more adaptive than required for their own operations, perhaps resulting in less than optimal use of the capacity.

Delays caused by congestion are not removed, but rather absorbed as smoothly as possible by integration of a broad range of planning activities.

7.5.4.2 Metrics

Two direct measures of the benefits of Integrated Arrivals and Departures Management are:

- reduced overall delays for flights to congested and/or disrupted airports;
- improved flight economy for flights approaching such airports, i.e. avoiding re-routing, deviations and holdings.

At the other side, "negative" metrics may be measured:

- planning problems at airports where departure planning is seriously affected by problems at one or more destination airports;
- dissatisfaction of AOs for delays caused by problems outside the scope of their direct interest;
- possible misuse of prioritisation, and the risk of an unfair allocation of penalties.

7.5.5 Dependencies

AOC and airport planning systems must be integrated with Arrivals Management and Departures Management as described elsewhere in this paper to provide a much-improved exchange of information. The result of these CDM applications will be that AOC and Airport planning constraints can be visible to departure and arrival managers and can be taken into account by them.
Another constraint is that accurate flight planning data must be commonly available and exchanged. Planning based on trajectory predictions should be in general use, and the related information exchanged between all ATC centres and CFMU.

7.5.6 Problems and Further Studies Required

The development of a CDM application for Integration of Arrivals and Departures Management raises several issues for research. A first question should concern the problems of convergence and stability of the planning process. A second general topic will be to consider the different aspects of prioritisation, pricing, and algorithm development.

Convergence of planning would concern questions such as:

- How large a time window should be used for arrival planning to fit adequately to the CFMU ATFM planning and how refined can be such a capacity planning?
- How much traffic can be prioritised without instability (too many conflicting departures)?
- How should other actors, such as AOC, provide their preferences and constraints?

The second topic, about prioritisation criteria, concerns questions such as:

- How to devise a prioritisation scheme which is convergent in itself, i.e. which ultimately will keep all scheduled arrival traffic as close as possible to the scheduled departure and arrival times?
- How to ensure that traffic between non-congested departure and destination airports are penalised only to such an extent as is considered generally acceptable?

Simulation assessment, probably using Fast-Time Simulation, will certainly be necessary as an element in the research activity necessary to develop this application.
7.6 Autonomous Separation in Free Flight Airspace
Free Flight airspace (FFAS) is an important element of the proposed operational concept defined in the EATMS OCD. Aspects include the ASM tasks of provision of FFAS and ATC tasks of implementation of delegation of separation assurance or free manoeuvring. It includes many collaborative elements, both in terms of improved information distribution and reallocation of decision making authority.

The topic is being addressed in many other projects, such as FREER [EEC] and Flight 2000 [FAA]. As a result, this application has not been developed in detail by the present project.

7.7 Meteo Information Exchange
This application concerns the distribution and sharing of meteorological information in order to improve the ability of users to take into account the impact of meteorological conditions. Principally this will include wide distribution of:

- pilot reports, particularly concerning severe weather;
- wind and temperature updates from on-board sensors;
- output of meteorological service providers.

In addition, when the capability becomes available, this should be extended to include distribution of short-term nowcast reports.

In the US, airline companies are already supplying a great deal of sensor information to enable ATC to provide a better picture of local meteorological conditions and to help improve forecasts. In Europe, some related work has been initiated through the EU DGVII WEATHER project. The improved sharing of information means that this can be regarded as a collaborative activity.

Since there is a significant level of work elsewhere to develop this activity, involving meteorology specialists, this application has not been developed in detail by the present project.
8. AIRPORT AIR TRAFFIC CONTROL

Six potential applications of CDM have been identified within the [ATM2000+] core process of Airport Air Traffic Control. They are described in the sections 8.1 to 8.6.

- **Collaborative Stand and Gate Management.** There are many uncertainties which airport resource managers have to deal with when trying to optimise the allocation of aircraft to gates and maximising throughput of passengers and aircraft. Collaboration to make this process easier and more efficient could take several forms. One example would be delegation of responsibility for managing a set of stands to an airline, as already happens at some airports. A second example is the improved provision of information on planned rotations and passenger numbers (from AOs) and on Estimated Times of Arrival (from ATC or AOs).

- **Departures Management 1: Estimation of Take-Off Time.** Estimated Time of Departure (ETD) is a key piece of information prior to take-off. The objective of this application is to provide more accurate, shared estimates of departure time, simply by better distribution of information that is already available. Existing predictions of Take-Off Time are the slot time calculated by CFMU (only approximate but nevertheless an update on the estimate of departure time which is given by flight-planned EOBT) and departure ATC’s estimate of Take-Off Time (representing a more accurate refinement). This information should benefit all recipients by allowing them to plan departures more effectively.

- **Departures Management 2: Estimation of Off-Block Time.** This application aims to provide, to all actors concerned with departures planning, a reliable estimate of the time at which a flight will call for start-up. Departures planning could thus be based on an updated estimate of Off-Block Time (OBT), rather than the initial EOBT on the flight plan, improving the effectiveness of the planning processes and increasing the opportunity for optimisation of the departure sequence. Collaboration between the many actors involved in preparing for the departure of a flight will be essential in order to realise accurate estimates.

- **Departures Management 3: Collaborative Departure Sequencing.** This application proposes to enable actors other than Tower ATC to influence the planned departure sequence, according to their own priorities. This would provide increased flexibility of operations for AOs and for the Airport Authority, allowing more efficient operations. Shared, accurate estimates of OBT are an essential pre-requisite.

- **Disruption Recovery 1: Information About Disruption.** This application and the next one concern significant, unplanned losses of capacity at a single constraint in the Air Traffic system, which result in severe disruption to traffic schedules. Access to the latest information about the problem and its effects will enable airlines (and any other actors affected) to make better decisions about their responses. The aim of this application is to put in place mechanisms and processes required to provide such information. Accurate, up-to-date and shared information in cases of disruption is expected to enable collaborative responses, aiding the speed of recovery of the system as a whole.

- **Disruption Recovery 2: Departures from Nearby Airfields.** One example of a collaborative response to disruption is to expedite departures from nearby airports that are bound for the airport or sector with severely reduced capacity. This will minimise the capacity wasted when a problem is resolved more quickly than assumed in the planning process (which must be pessimistic for safety reasons). Both users and providers benefit.
8.1 Collaborative Stand and Gate Management

8.1.1 Context
Airports can be capacity-constrained for several reasons, one of which is a shortage of stands or gates. Management and allocation of stands, gates and other airport resources are usually the responsibility of the Airport Authority, who may also be responsible for controlling movements on the Apron. Ground Movements Control and ATC for arriving and departing aircraft is provided by the Air Traffic Services provider. Ground Movements Control can be thought of as the interface between the Ground and Air sides at an airport.

There are many uncertainties which airport resource managers have to deal with when trying to optimise the allocation of aircraft to gates and maximising throughput of passengers and aircraft. For example, the best information which airport managers normally have on the imminent requirement for a gate is gathered by someone eavesdropping on the ATC frequency. Also, there is little or no warning that the gate will be freed by the aircraft until it is actually requesting push-back.

8.1.2 Description
Collaboration could take several forms. One example would be delegation of responsibility for managing a set of stands to an airline. This process already happens at certain airports (e.g. Air France at Orly, British Airways at Heathrow). A second example is the improved provision of information on planned rotations and passenger numbers (from AOs) and on Estimated Times of Arrival (from ATC or AOs). Airport Authorities’ resource allocation task would be made easier and more efficient if this information could be provided earlier and more reliably, and with updates as the AOs’ own plans become more precise.

Aspects of Stand and Gate Management are considered in the Departures Management applications in sections 8.2, 8.3 and 8.4 below, and in the Arrivals Management applications in sections 7.3 and 7.4 above.
8.2 Departures Management 1: Estimation of Departure Time

8.2.1 General Description

8.2.1.1 Context
Estimated Time of Departure (ETD) is a key piece of information prior to take-off. For flights not yet airborne, it is the basis on which all flight timings including ETA must be estimated. However, accurate estimates of departure time are not widely available in the current air traffic system.

The current departure process is illustrated in figure 8-1.

Pre-departure planning by all actors is initially based on the Estimated Off-Blocks Time (EOBT) given in the flight plan. However, the actual time at which a flight departs (Actual Take-Off Time, ATOT) can be significantly different from this because:

- Actual Off-Blocks Time (AOBT) can be significantly later than the flight-planned EOBT due to delays in airline operations or because of ATFM slot delays;
- the actual time between off-blocks and take-off (that is, the time taken to push back, taxi and queue to use the runway) is very variable.
Some actors generate or have access to more accurate estimates of Take-Off Time (TOT), as illustrated in figure 8-1:

- For regulated flights, CFMU calculates the slot time (Calculated Take-Off Time, CTOT) and passes it to AOC and Departure ATC.
- After the pilot has requested start-up clearance, Departure ATC plans the departure sequence and estimates the flight’s take-off time. In general, this estimate is not disseminated, although in some cases it is entered into the national ATC system. It is referred to as Estimated Time of Departure (ETD).

Currently, those updates to a flight’s departure time that exist are not distributed as widely as they could be, and in general there is no accurate, shared estimate of TOT (i.e. no accurate, shared ETD). This limits the effectiveness of departures planning for a number of actors.

8.2.1.2 Objectives and Benefits

The objective of this application is to provide more accurate, shared estimates of departure time, simply by better distribution of information that is already available. (The next application, in section 8.3, looks at how earlier and better predictions of departure time could be obtained.)

The existing predictions of TOT are:

- i. CTOT (for regulated flights only), i.e. the slot time calculated by CFMU. Since the actual TOT may be anywhere in the range CTOT -5/+10 minutes, this gives only an approximate estimate of departure time. It does, however, represent an update on the estimate of departure time which is given by flight-planned EOBT.
- ii. ETD, i.e. departure ATC’s estimate of TOT. This is a refinement of CTOT (for regulated flights).

The objective is therefore to distribute these predictions of TOT to all interested actors, and to have those actors use those predictions in their own processes.

This should benefit all recipients of the information by allowing them to plan departures more effectively.

In addition, there may be knock-on, system-level benefits to other actors. More effective planning should result in the more-efficient use of scarce resources (such as runway and airspace capacity, and airport stands), providing greater efficiency and, ultimately, reduced delays.

8.2.1.3 Collaborative Decision Making Aspects

Providing a shared understanding of critical parameters such as ETD is an essential step towards enabling Collaborative Planning and Decision Making in the air traffic system.

Examples of collaborative processes enabled by the use of a common and accurate ETD are:

- collaboration between ATC and AOC in trajectory planning, as discussed in the In-Flight Traffic Management application, section 7.2;
- better estimation of arrival times, enabling optimisation of arrivals sequence, as discussed in section 7.4;
- Collaborative Departures Sequencing, as discussed in section 8.4.

The ATFM slot is CTOT -5/+10 minutes.
8.2.2 Description of Process

8.2.2.1 Actors
The following actors are sources of existing information about TOT:

- **CFMU** - generates CTOT for regulated flights;
- **Departure ATC** (i.e. Tower at the departure airport) - generates ETD (an estimate of TOT) after a flight has requested start-up clearance.

The following actors are potential recipients and users of that information:

- **Stand Allocation Unit (SAU) at the departure airport (ADEX)** - would use CTOT to update initial EOBT in stand allocation planning;
- **AOC** - many already receive CTOT; could use ETD in their operations control and dispatch processes;
- **ACCs** through whose airspace a flight will pass - could use both CTOT and ETD to update the flight plan information on which their planning processes depend;
- **Arrival ATC** at a flight’s destination airport - could use both CTOT and ETD to update ETA in their planning process;
- **SAU at the destination airport (ADES)** - could use both CTOT and ETD to update ETA in their planning process;
- **CFMU** - could use ETD in Tactical ATFM to improve its picture of current and expected traffic loads.

8.2.2.2 Information Flows and Processes
There are a number of possible ways in which information could be routed from its source to the required recipients. Two options are presented here:

- **Option 1** - CFMU acts as a central repository and distributor of CTOT and ETD (illustrated in figure 8-2);
- **Option 2** - local exchanges are used where these exist already or are likely to be needed for other purposes; builds on existing links (illustrated in figure 8-3).

Figures 8-2 and 8-3 illustrate the actors involved, the relevant processes and the information exchanged. Note that in both diagrams, CTOT would be distributed earlier than ETD.

In practice, a system is likely to evolve that includes elements of both these options, depending on existing local infrastructure and development priorities. For example, some ATC Towers will be linked directly to CFMU, while others will send and receive information via their local ACC (as is the case today).

In either option, Arrivals ATC and SAU may prefer to receive updates to ETA, which are directly useful to them, rather than the “raw” CTOT and ETD. Both CFMU and Arrivals ACC are likely to require ETA updates themselves, and so either could generate and forward these updates.
Figure 8-2: Distribution of CTOT and ETD - option 1: fully centralised.
8.2.2.3 Interfaces

In order for the identified information exchanges to take place, electronic links would be required between the actors. In order that large volumes of information can be easily used by the recipient, exchanges should be automatic—directly between computer systems without the need for an operator to read a value off a display and enter it into the local system.

For option 1:

- A two-way link is required between CFMU and Departure ATC. There is an existing link from CFMU to Departure ATC (AFTN for delivery of FPLs), sometimes via the local ACC’s ATC system. In many cases, an operator is required to transfer the CTOT into the ATC system, although a number of ACCs are currently procuring new interfaces to allow automatic transfer. The existing link from Departure ATC to CFMU is usually via the local FMP, by telephone. A new link would be required to pass ETD back to CFMU electronically. Automatic transfer would be preferable to minimise ATC workload.

- A one-way link is required from CFMU to all the other actors. This link already exists to all European ACCs and Arrival ATC units, as well as to many AOCs. However, few of the existing interfaces allow automatic transfer—new interfaces would be required for efficient use of the incoming information. New links are required to the SAUs.

As an alternative to these point-to-point links with CFMU, option 1 could be implemented via a shared-access virtual database with network connections for all participants. The
database would be physically distributed. Information could be added to this “virtual information pool” by any actor. Actors would subscribe to items of interest to them, and their systems would then be updated automatically following any changes to those elements. Section 4 of the present report provides further discussion of the Virtual Information Pool concept.

The concept is similar to the World Wide Web, but because of the real-time nature of the information requirements (and also perhaps because of security issues) a dedicated network might be required. The example of the US AOCnet [RTCA] should be investigated.

For option 2:

- Electronic data exchange between Tower ATC and the ACC’s ATC system would be required, and is already present in some cases.

- Electronic data exchange between ACC’s ATC systems (FDPSs) and CFMU would be required. As noted above, there are existing links from CFMU to ACCs, although the interfaces are often manual. Two-way, automatic links would be required. Alternatively, electronic data exchange between ACC’s FDPSs could be used. (An additional link with CFMU would still be required if ETD were to be used to improve its picture of current and expected traffic loads.)

- An electronic link would be needed between each Tower and its local SAU(s). In some cases, such a link already exists.

- An electronic link would be needed from CFMU to all participating AOCs. This link already exists to many AOCs: the CFMU terminal (or RTA). However, the existing interface does not allow automatic transfer of information—new interfaces may be required for more efficient use of the incoming information.

8.2.3 ATM2000+ Timescale

This application is proposed as a near term part of the Improved Surface Management area of system improvement [ATM2000+]. That document indicates that FDPS interoperability between ACCs can be expected before 2005. Initial implementations of this application should be possible in the timeframe 2000–2002, if work is initiated promptly.

8.2.4 Evaluation of Costs and Benefits

8.2.4.1 Areas of Cost and Benefit

If automatic, electronic data exchange is used, no significant additional operating costs are foreseen.

A relatively small amount of investment would be required to put in place the data links and automatic interfaces required.

The following benefits are foreseen:

- **For SAU at departure airport**: Knowledge of CTOT would provide the SAU with warning that a flight was expected to remain on its stand longer than originally scheduled. This should enable more effective planning, making more efficient use of the stands available, and thus increasing revenue and customer satisfaction.

- **For SAU at destination airport**: CTOT and ETD contribute to an earlier and more accurate estimate of arrival time. Again, this should enable more effective planning, making more efficient use of the stands available, and thus increasing revenue and customer satisfaction.
• **For ACCs and Arrivals ATC:** In general, an ATC unit can only make accurate trajectory predictions for a flight once that flight is within range of radar systems. This limits the length of time in advance that planning and problem solving can be done. In particular, since there is no accurate ETD, predicted trajectories for aircraft that have not yet taken off are much less accurate than those for airborne traffic, and hence cannot be included in planning and problem-solving for en-route traffic. The availability of an accurate ETD from start-up time (say, 10mins ahead of take-off) would significantly increase the predictability of a body of en-route traffic, making planning more feasible. This would allow more problems to be planned out strategically, thus reducing tactical workload and increasing sector capacity.

• **For AOC:** AOCs’ processes include adjusting staff rosters and fleet planning to protect the schedule, and preparation for subsequent aircraft turn-arounds. Advance knowledge of delays (through CTOT) and advance estimation of TOT should improve the efficiency of these planning processes. In addition, the AO can expect knock-on benefits as a customer of the other actors: increased sector or airport stand capacity would benefit AOs, and strategic solution of some ATC problems should reduce tactical conflict-avoiding action, resulting in a less disrupted, and therefore more optimal, trajectories for the aircraft.

### 8.2.4.2 Metrics

Direct measures to indicate the success of this application would be:

- the accuracy of planning estimates (ETD or ETA, depending on the actor) in use by a given actor at a range of times, both before and after Take-Off;
- whether the same (or consistent) estimates are being used by different actors.

The resulting benefits could be assessed by estimating changes in:

- feasible planning horizon for each actor’s planning process(es);
- utilisation rate for stand capacity.

When weighing up the cost of implementing this application against the benefits to be gained it should be taken into account that the new information exchanges outlined here would subsequently enable further developments in CDM for departing flights, allowing additional benefits to be realised later.

### 8.2.5 Dependencies

This application has close links with existing work on A-SMGCS. In order for Departure ATC to continue to provide accurate estimates of TOT as Ground Movements Control becomes more complex, it may be necessary to employ an automated ground movements planning tool, such as an A-SMGCS. Furthermore, an A-SMGCS would enable distribution of ATC’s planning estimates to other actors at the airport.

Related to this application is the issue which CFMU are currently examining, concerning taxi time. At the moment, for a flight that is regulated but not delayed, CFMU calculates CTOT from EOBT and a standard taxi time for that airport. If the standard taxi time is too short (for example if the airport is congested), this may result in a flight being given a CTOT that is too early for it to meet. To improve on this present situation, CFMU would need more accurate estimates of taxi time. Departure ATC could send such estimates to CFMU. A simple

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9 Fast-time simulation study [Magill97] has shown that in European airspace, for a 20-minute planning horizon, 46% of conflicts would involve at least one flight that was not airborne at the time the planning was being done (based on traffic above 10,000 feet).
estimate of taxi time would be based on the standard taxi time but also take into account expected congestion at the airfield at EOBT (i.e. a few hours ahead). A more sophisticated implementation could also consider expected runway in use and expected stand allocation for the flight in question. Such precise handling of taxi times would probably require computerised support, such as an A-SMGCS.

8.2.6 Problems and Further Studies Required

The following areas merit further investigation:

- The most cost-effective routes for the required information exchanges—local links or centralised storage and distribution. Electronic links required for other information exchanges should be considered, with the aim of reducing the cost of implementing each exchange. For example, this application overlaps with the issue of sharing flight plan information between ATC Units. The broader picture of information exchange should be borne in mind in the implementation of this application.

- Modifications to each planning process to enable best use to be made of the new information.
8.3 Departures Management 2: Estimation of Off-Block Time

8.3.1 General Description

8.3.1.1 Context

The current departure process is illustrated in figure 8-1 in section 8.2.1.1.

Pre-departure planning by all actors is initially based on the Estimated Off-Blocks Time (EOBT) given in the flight plan. However, the Actual Off-Blocks Time (AOBT) can be significantly later for many reasons, including delays in airline operations and ATFM slot delays.

The turn-around of a particular airline’s flight at a particular airport may be co-ordinated by airline staff, by a handling agent or by the pilot himself, depending on the airport and the airline involved. As preparation for the flight progresses, the pilot and/or the “ground operations co-ordinator”, maintains a mental working estimate of his expected Off-Block Time (OBT), based on information from the various service providers at the airport (caterers, cleaners and so on). If the turn-around is at the airline’s home base, the AOC may be kept appraised of progress, but this is rarely the case for flights departing from other stations.

When the flight is ready to depart, the pilot requests start-up clearance from Departure ATC, often via Apron Control. At this time, ATC plans the flight’s approximate position in the departure sequence and issues clearance to start up. (If the flight is regulated, this clearance is of course subject to the flight’s predicted TOT being within its CFMU slot. If the slot has been missed, the Tower must negotiate an extension with CFMU, or the Airline must obtain a new slot.)

ATC, Apron Control and the Stand Allocation Unit (SAU) in general receive no reliable warning of when a flight will be ready to call for start-up. So for these actors, accurate pre-departure planning can begin only once a flight has called for start-up. This limits the effectiveness of departures planning processes. For example:

- Possibilities for optimisation (for any reason) of the departure sequence are limited. At many airports, there are limited opportunities for overtaking during taxi or in the queue for the runway (although one example is the use of different holding points for aircraft of different wake vortex categories). Hence the departure sequence is partially determined by the order in which flights call for push-back and their distance from the runway. If a higher-priority flight calls for push-back shortly after a lower-priority one, there is often no chance to prioritise as required, since the lower-priority flight will already have started its push-back and taxi.

- Tactical stand allocation, although based on a plan, is often a reactive process since there is little or no advance warning of the precise time at which a stand will be free.

8.3.1.2 Objectives and Benefits

The objective of this application is to provide, to all actors concerned with departures planning, a reliable estimate of the time at which a flight will call for start-up.

An initial aim might be to make such an estimate available 20 minutes in advance of initial (i.e. flight-planned) EOBT. So for example, if a 10-minute delay was forecast, the estimate would be available 30 minutes before the expected OBT. Updates should be sent as appropriate, for example in the event of a problem which results in a delay being discovered or solved.

This would allow departures planning to be based on an updated estimate of OBT (rather than the initial EOBT on the flight plan), improving the effectiveness of the planning
processes and increasing the opportunity for optimisation of the departure sequence. The updated estimate of OBT should become more reliable as OBT approaches.

An accurate estimate of OBT, available some time in advance, would also allow accurate estimates of TOT to be made earlier than start-up time. The benefits of accurate ETD are outlined in section 8.2 above; those benefits would be increased and extended by increasing the look-ahead time.

8.3.1.3 Collaborative Decision Making Aspects

Many actors are involved in preparing for the departure of a flight and there are many causes of uncertainty in OBT in today’s system. Collaboration between the actors will be essential in order to realise accurate estimates of OBT, since information will be needed from all concerned. Furthermore, improvements in collaboration could improve the efficiency and predictability of certain parts of the ground operations, for example, passenger handling.

The availability of reliable, shared predictions of OBT is an essential enabling step towards collaborative processes for departures. The possibilities for Collaborative Departures Sequencing are discussed further in the next application, in section 8.4.

8.3.2 Description of Process

8.3.2.1 Actors

Aircraft turn-around at an airport incorporates a number of services provided at the airport. A given service may be provided by different organisations at different airports. For example, passenger and baggage loading may be the responsibility of the Airline, a handler, or the Airport Authority (where the Airport Authority is responsible for providing handling services). Similarly, responsibility for co-ordinating the turn-around may rest with airline staff, with a handling agent or with the pilot himself. Therefore, to provide a generic discussion of this application, the actors identified here are based on functions rather than organisations.

Figure 8-4 shows the actors involved in this application. They are:

- **“Ground Ops Co-ordinator”**: responsible for co-ordinating the various elements of the turn-around, maintaining an estimate of the time at which the ground operations will be completed, and communicating this to the pilot. He should also pass updates to that estimate as appropriate, for example as a problem which results in a delay is discovered or solved.
- **Pilot**: responsible for maintaining an estimate of the time at which he will be ready for start-up, and passing this to ATC at least an agreed time in advance of the call for start-up. He should also pass updates to that estimate as appropriate, for example as a problem which results in a delay is discovered or solved.
- **Tower ATC**: responsible for advance sequencing of departures, based on the estimates of ready time available from the pilots. As happens today, ATC will co-ordinate with Apron Control at airports where this is a separate function. Based on the planned departure sequence, ATC will be able to make a reliable estimate of OBT and will distribute that estimate to interested actors. The availability of an accurate estimate of OBT and a planned departure sequence will allow ATC to estimate TOT (i.e. ETD) earlier than is currently possible. This estimate should be distributed as discussed in the previous application, in section 8.2.
- **Apron Control**: responsible for co-ordinating with ATC to sequence departures efficiently and to estimate OBT and TOT.
• All the ground operations that contribute to preparation for a flight, including passenger handling (including customs and police), baggage handling, cleaners, catering, fuel tankers, and push-back tractor providers will be responsible (as they are at present) for keeping the “Ground Ops Co-ordinator” appraised of the progress of their operations.

• AOC Operations Control, through the “Ground Ops Co-ordinator” may also have an input to preparations for the flight, and will therefore contribute to the estimate of ready time. AOC is also expected to be involved in this application as a recipient of the updated EOBT (and of ETD).

• The Stand Allocation Unit (SAU) is envisaged to be another interested recipient of the updated EOBT.

8.3.2.2 Information Flows and Processes

The information flows between the actors, and the processes involved, are illustrated in figure 8-4.

The information exchanges shown in figure 8-4 happen in three groups, ordered in time:

1. the “Ground Ops Co-ordinator” receives (or collects) information from the ground operations, forming his estimate of the time at which the turn-around will be complete, and keeping the pilot informed;

2. the pilot uses this information to estimate the time at which the aircraft will be ready to start, and; passes this estimate to ATC;
3. ATC plans the departure sequence, in co-ordination with Apron Control, and when it is stable passes estimates of OBT and TOT to the interested parties.

These steps may be iterated. For example, when a problem which results in a delay is discovered, or solved, the pilot may send an updated estimate to ATC. As a result, ATC may re-sequence the departures, providing new EOBT and ETD for affected flights.

Estimates of the times at which flights will be ready to start will only be useful for departures sequencing if they are reasonably stable. Similarly, EOBT and ETD will not be useful to other actors unless they are reasonably stable. There will be a trade-off between how far in advance estimates are made available and their stability. A suitable look-ahead time will need to be agreed by all participants, but an initial proposal is that pilots should aim to provide 20 minutes’ warning of their call for start-up.

The recipients of the estimates need to know how much confidence they can have in the estimates supplied. Consideration should be given to providing estimates together with a simple confidence rating.

The process of maintaining an estimate of the time at which the flight will be ready to depart is performed today by the pilot, as part of his task of managing the flight. Although the process could be performed by a different actor in future, it appears that the pilot is most appropriately placed to be the focus for this decision.

Today, departure sequence planning is manual at almost all airports. ATC first plans a flight’s approximate position in the departure sequence when the flight calls for start-up. The departure sequence therefore depends on:

- the time at which a flight calls for start-up;
- time controller’s experience of how long the process of start-up, push-back, taxi and take-off will take, including any necessary queuing;
- the flight’s CFMU slot time;
- any delay in issuing start-up clearance because of airfield or apron congestion.

This application proposes providing ATC with advance warning of the time at which a flight will be ready to start, allowing departure sequence planning to occur in advance, and hence increasing the opportunity for departures to be ordered so as to optimise runway or taxiway utilisation. Departures sequencing would therefore become a more complex process than it is today.

Adding a feedback loop to this application, allowing other actors to influence the planned departure sequence, opens up possibilities for collaborative departure sequencing. These are discussed in the next application, in section 8.4.

Some airports already have (or are procuring) systems allowing ATC and/or SAU to be aware of operations at the gate. Examples include automatic docking systems, CCTV and push-button units for staff at the gate to indicate the progress of passenger loading. Such systems could provide ATC with independent information on the progress of ground operations, and hence the time at which the aircraft might be ready to depart.

### 8.3.2.3 Interfaces

Verbal interfaces between the pilot and the various ground operations already exist. The existing interfaces would be sufficient for the implementation of this application.

A verbal (radio) interface already exists between the pilot and ATC. This would be sufficient for initial implementation of this application. Alternatively data links could be used to pass the pilots’ estimates to the Tower and vice versa, reducing the ATC workload associated with this application. This would be in line with existing proposals to use data links for
passing pre-departure clearances to the aircraft and for downloading aircraft parameters to ATC. In particular, the proposed gatelink system—initially envisaged to provide a data link between AOC and cockpit—could be used for this purpose.

Electronic links would be required from ATC to the other actors interested in receiving updated estimates of OBT: AOC/Airline Station Manager, SAU and Apron Control. Such links already exist at some airports.

8.3.3 ATM2000+ Timescale
This application is proposed for implementation in the medium term (from around 2003), within the Improved Surface Management area of system improvement [ATM2000+].

8.3.4 Evaluation of Costs and Benefits

8.3.4.1 Areas of Cost and Benefit
No significant additional operating costs are foreseen.

A relatively small amount of investment would be required initially:

- to put in place the data links and automatic interfaces required (but note that these are likely to be required for other purposes as well);
- to agree operational procedures relating to the estimation and reporting of the time at which the flight is expected to be ready to start, and to how that estimate is used in departure planning.

Advance warning of the time at which a flight will be ready to start is envisaged to benefit the following actors:

- **Departures ATC** - by increasing the scope for optimisation of the departure sequence to maximise runway or taxiway utilisation, and/or to minimise controller workload.
- **Apron Control** - planning the order of start-ups and push backs in advance would allow more efficient use of the apron space, minimising congestion.

It is envisaged that an accurate update to EOBT could improve the effectiveness of the planning processes of the following actors:

- **SAU** - tactical stand allocation planning could become less reactive and more effective, improving stand utilisation.
- **AOC/Airline Station Manager** - AOCs’ processes include adjusting staff rosters and fleet planning to protect the schedule, and preparation for subsequent aircraft turn-arounds. Advance knowledge of delays, through updated EOBT, should improve the efficiency of these planning processes.

In addition, the AO should benefit in terms of improved service from ATC, Apron Control and the SAU. For example, AOs would benefit from increased efficiency in the utilisation of runway, apron or airport stand capacity.

An accurate estimate of OBT, available some time in advance, would also allow accurate estimates of TOT to be made earlier than start-up time. The benefits of accurate ETD are outlined in section 8.2 above; those benefits would be increased and extended by increasing the look-ahead time.


8.3.4.2 Metrics

Direct measures to indicate the success of this application would be:

- whether ATC can plan a flight’s position in the departure sequence before the flight calls for start-up clearance;
- the accuracy of EOBT in use by a given actor at given times before take-off;
- whether the same (or consistent) estimates are being used by different actors.

The resulting benefits could be assessed by estimating changes in:

- runway utilisation;
- taxiway utilisation (at airports where taxiways are a critical resource);
- utilisation rate for stand capacity (at airports where stands are a critical resource), or improved meeting of airline preferences for stand allocated;
- efficiency of apron operations;
- feasible planning horizon for each actor’s planning process(es).

When weighing up the cost of implementing this application against the benefits to be gained it should be taken into account that the new information exchanges outlined here would subsequently enable further developments in Collaborative Planning and Decision Making for departing flights, allowing additional benefits to be realised later.

8.3.5 Dependencies

In practice, the current Flow Management system does not encourage pilots to report delays in ground operations to ATC where this will result in missing their ATFM slot. A mechanism such as Slot Shifting (see section 6.7 of the present report) will be needed to encourage AOCs to provide the required information.

The increased complexity of the departures sequencing process, resulting from earlier planning of the departure sequence, may eventually require computer support tools. Work on A-SMGCS is already considering these aspects of departures planning.

An accurate estimate of OBT, available some time in advance, would also allow accurate estimates of TOT to be made earlier than start-up time. Section 8.2 above discusses the distribution of ATC’s estimate of TOT to other actors; the interfaces required are described in section 8.2.2.3.

8.3.6 Problems and Further Studies Required

The trade-off between the stability of estimates and how far in advance they are made available should be investigated. A suitable look-ahead time will need to be agreed by all participants.

The frequency of updates that would be necessary to maintain the accuracy of estimates should be investigated. It will also need to be ascertained whether that frequency of updates could be supported by the participants’ systems.

It has been proposed that estimates could be provided together with a simple confidence rating. Users’ opinions on the usefulness of this kind of “qualified” estimate should be investigated, perhaps via a simple trial. A standard scale and assessment method should be agreed.
8.4 Departures Management 3: Collaborative Departures Sequencing

8.4.1 General Description

8.4.1.1 Context
Accurate prediction of Estimated Off-Blocks Time (EOBT), as discussed in the previous application (section 8.3), should increase the opportunity for optimisation of the departure sequence.

At many of Europe’s major airports the first priority is likely to remain maximising runway utilisation, since runway capacity is likely to remain the most critical factor. However within that, and certainly at airports where runway capacity is less of a constraint, there may be scope for optimisation according to other actors’ priorities: for example to meet CFMU slots, to vacate critical stands, to expedite AO’s critical flights.

8.4.1.2 Objectives and Benefits
The objective of this application is to allow actors other than Tower ATC to influence the planned departure sequence, according to their own priorities. This would provide increased flexibility of operations for AOs and for the Airport Authority, allowing more efficient operations.

8.4.1.3 Collaborative Decision Making Aspects
This application introduces collaboration into ATC’s departures planning process. The final decision on departure sequence is envisaged to rest necessarily with ATC, making this is an example of Collaborative Planning rather than Collaborative Decision Making.

Another aspect of this application is that, since Airlines and Airport Authorities have an interest in the agreed departure sequence, they are more likely to contribute to achieving the planned OBT and maintaining the planned sequence. Therefore, there may develop a combined, collaborative processes of determining EOBT and then ensuring that prediction remains accurate.

8.4.2 Description of Process

8.4.2.1 Actors
The actors involved in this application, and the interactions between them, are illustrated in figure 8-5.

- **The Pilot** is responsible for passing ATC an estimate of the time at which his flight will be ready to start, as discussed in the previous application (section 8.3).
- **Departure ATC** is responsible for planning the departures sequence, and for controlling flights on the airfield in accordance with that sequence. (Also for controlling flights as they take off, as now).
- **Apron Control** is responsible for controlling vehicles on the apron, and co-ordinates with Departure ATC in the process of departure sequencing. (At some airports there are different Apron Control Units for the aprons around different terminals.)
- **The Stand Allocation Unit (SAU)** (at some airports there are different SAUs for different terminals), and the **AOC**—represented by the Airline’s Station Manager or Handling Agent except at the home base, are responsible for proposing changes to ATC’s planned
departure sequence to take into account their own priorities (see also section 8.1, Collaborative Stand and Gate Management). It is envisaged that these actors might negotiate to ensure that they are requesting compatible changes.

There will not be time for extended negotiation, so one of the actors needs to have responsibility for keeping control of the process. In addition, responsibility for the safe and expeditious flow of aircraft remains with ATC, and ATC has to be able to control flights in accordance with the finally-agreed sequence. Hence ATC is envisaged to remain the final arbiter in deciding the departure sequence. That is not to say, however, that the process is not truly collaborative. There may be time for some negotiation, and in any case the AOs and SAUs will have the opportunity to provide their preferences for prioritisation of flights. Both these outcomes are recognised examples of collaborative processes (collaboration levels 3 and 4 in section 3.3).

![Figure 8-5: Actors and interactions in Collaborative Departures Sequencing](image)

### 8.4.2.2 Information Flows and Processes

The order of the information exchanges and processes proposed is shown in figure 8-6.

A single iteration is envisaged, because there will be only a limited amount of time between a reliable estimate of a flight’s ready time being available and the flight’s actual departure. ATC is not expected to arbitrate between AOs and SAUs. It will apply pragmatic solutions, based primarily on ATC priorities but taking into account the priorities of other actors where possible.
Of course, ATC will receive a continuous stream of pilots’ estimates of “ready time”. Today, the departures sequence is planned as a continuous process. In order to communicate a part of that sequence to other actors, and negotiate about it, that part of the sequence must be frozen. The length of the piece of the sequence that could be considered at one time, and the most effective timings of the “freezing” and negotiation, would need to be determined.

The keys to this process working successfully will be

- accurate and stable predictions of EOBT;
- good information exchange;
- a set of rules for what changes are acceptable, agreed by all participants and all airline.

These two, taken together, should ensure that the large majority of proposals received by ATC will be approved. If this were not the case, the process would waste time.

As well as being enabled to optimise the departure sequence for runway or taxiway utilisation, Departure ATC might be able to take into account priorities of other ATC Units. For example, it might be possible to prioritise departures to a destination that has spare capacity, having recently had a Flow Management regulation relaxed (because of improved weather or corrected technical problems, for example).

A link might also be possible with Arrivals Management at the same airfield.

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**Figure 8-6: Information Exchange in Collaborative Departures Sequencing**

1. Pilot sends ATC estimate of time his flight will be ready to start.
2. ATC plans departure sequence in co-ordination with Apron Control, and optimised according to those two actors’ priorities. Conclusions forwarded to other actors.
3. AOC/Station Manager assesses required changes, in co-ordination with Pilot. SAU assesses required changes. Possible negotiation to ensure consistent changes are requested. Required changes sent to ATC.
4. ATC approves changes and recalculates departure sequence. Updated estimates forwarded to other actors.
8.4.2.3 Interfaces
Rapid, electronic information exchange would be required between ATC and AOC/Station Manager, and between ATC and SAU, to enable the departure sequence and proposals for change to be communicated.

An effective way of displaying the sequence to each actor, allowing them quickly to assess the sequence and the options for change, may also need to be developed. The negotiation between actors would be simplified if such a display were shared.

8.4.3 ATM2000+ Timescale
This application is proposed for implementation in the longer medium term (from around 2005), within the Improved Surface Management area of system improvement [ATM2000+].

8.4.4 Evaluation of Costs and Benefits

8.4.4.1 Areas of Cost and Benefit
Running costs of Collaborative Departures Sequencing will arise principally from the staff needed to participate in the process.

Initial investment would be required:

- to develop and agree a set of rules and operational procedures for Collaborative Departures Sequencing;
- to develop and procure the supporting communications and display infrastructure (see section 8.4.5 below).

The beneficiaries of this application are envisaged to be:

- **AOC** - enabled to prioritise critical departures;
- **SAU** - enabled to prioritise the freeing of critical stands;
- **ATC** - better system functioning because wider priorities can be considered in departures sequencing;
- **ATFM** - slot compliance would be improved through the existence of a formal departures prioritisation process.

8.4.4.2 Metrics
The utilisation rate for critical stands could be measured to assess the benefit to the SAU.

A measure of Airline operational efficiency would need to be developed.

8.4.5 Dependencies
This application depends on the availability of reliable and timely estimates of OBT and TOT, as discussed in the previous two applications (sections 8.2 and 8.3).

Introducing additional parameters into departures sequencing makes it a much more complex process. Computer support tools would be needed to enable controllers to handle this additional complexity.
8.4.6 Problems and Further Studies Required

- Development of operational procedures, and a set of rules. Since it is proposed to move away from a first-come-first-served sequencing, agreement of all concerned on the issue of equity would need to be negotiated.

- The length of the piece of the sequence that could be considered at one time, and the most effective timings of the “freezing” and negotiation, would need to be determined.
8.5 Disruption Recovery 1: Information About Disruption

8.5.1 General Description

8.5.1.1 Context

This application and the next one (in section 8.6) consider the situation where there has been a significant, unplanned loss of capacity at a single constraint in the Air Traffic system, resulting in severe disruption to traffic schedules.

Such loss of capacity can occur in ATC sectors as a result of system failures, communications failures or power failures. Another possible cause is industrial action. When this occurs, it may not be known how many controllers will be available for the next shift until they arrive at work a few minutes before the shift is due to start.

Severe losses of capacity occur most commonly at airports, however, and for that reason this application has been placed within the Airport ATC section of the present report. Severe loss of capacity may arise at an airport for a number of reasons including:

- fog or low cloud which significantly reduces RVR;
- cross winds forcing a lower-capacity combination of runways to be used;
- very strong winds reducing the approach speed of the traffic;
- lying snow or ice on the airport surface;
- unavailability of a runway as a result of accident or fire;
- unavailability of stands or terminal as a result of accident or fire;
- equipment failures;
- industrial action.

The disruption to schedules that results from these losses of capacity can be considerable—airline schedules, aircraft and staff allocations can take several days to recover to their "normal" state. Airlines therefore view these disruption conditions as a very significant problem.

CDM could be applied to improve the recovery of the system from such disruption, reducing the period over which schedules are disrupted.

In the current system, efficient recovery from disruption relies strongly on co-operation between different parties. However, the co-operation is mostly ad-hoc and information exchanges manual, for example by telephone requests and discussions. It may be that by encouraging and facilitating exchange of information and introducing collaborative procedures, disruption recovery can be improved considerably.

In response to a severe, unplanned capacity drop, CFMU sets a regulation to control the flow of traffic to the constraint. This does not begin to take effect for some time because it does not affect traffic already airborne. In the meantime the traffic must be dealt with on a tactical basis. The applications on In-Flight Traffic Management and Optimisation of Arrivals (sections 7.2 and 7.4) suggest collaborative processes that could apply here: enabling ATM and AOC to be aware of the disruption and how it is expected to progress, and to collaborate in minimising its effect, deciding which flights to divert and which to hold.

Another example of collaboration to reduce the effect of a major loss of capacity is given by the Substitution on Cancellation application, in section 6.6.
8.5.1.2 Objectives and Benefits
An important element in enabling a collaborative approach to disruption recovery is the availability, to all parties concerned, of information on the problem and on current assessments and predictions of its effects on the Air Traffic system. The aim of this application is to put in place mechanisms and processes that allow such information to be available to, and shared by, all those involved in dealing with the disruption.

Initially, access to the latest information about the problem and its effects is expected to allow airlines (and any other actors affected) to make better decisions about their responses. Subsequently, it is expected to provide opportunities to make those responses collaborative, aiding the speed of recovery of the system as a whole.

8.5.1.3 Collaborative Decision Making Aspects
Up-to-date information on the problem and its currently-foreseen effects, common to all participants, is an essential first step towards introducing any collaborative process. Recovery from a “crisis” that has caused significant disruption to schedules is already recognised by many actors as a shared problem, and one that is best addressed by co-operation. Given that, it may be that simply providing common and up-to-date information will allow effective collaborative solutions to evolve.

In any case, this application can be seen as a crucial stage in the development of collaborative disruption recovery processes.

8.5.2 Description of Process

8.5.2.1 Actors
ATC, Airport Authorities and Aircraft Operators are all affected by the “crises” identified, and all have an interest in minimising the disruption caused, and recovering normal operations as quickly as possible.

The most appropriate actor (or combination of actors) to supply information about the problem and how it is affecting capacity depends on the nature and location of the problem. Examples are discussed in the next section (8.5.2.2), involving: meteo information providers, Airport ATC, Airport Authorities and ATC Units

CFMU could be involved as a central focus for holding and distributing information, and as a source of flow management information.

AOCs are involved principally as users of the information, in their flight planning processes. Given accurate and complete information, they will be enabled to take better decisions about whether and how to re-route, divert or cancel flights.

8.5.2.2 Information Flows and Processes
Information is required about:

• the cause of the problem;
• the local assessment of the status of the affected airfield, runway, terminal or airspace;
• the delays currently resulting;
• the current forecast as to how each of the above will develop with time;
• possible alternatives (status of diversion routes, airfields, …).
The exact actors and information involved depends on the nature and location of the problem. For example:

- Where weather conditions are the cause of the problem, **meteo reports and forecasts** (supplied by **meteo information providers**) are used.
- Where loss of runway capacity at an airport is involved, **Airport ATC** would assess the effects of the problem and decide the resulting **status of the airfield and runway(s)**. It is this status information, and the forecast for how it will change with time, that is most useful to Airlines and other airport users.
- The **Airport Authority** would need to provide information about any problem with **terminal facilities or stands**;
- For loss of capacity in en-route sectors or areas, an **ATC Unit** (ACC or FMP) would supply information about **current and expected ATC capacity**.

Figure 8-7 gives an example based on loss of runway capacity at an airfield.

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**Figure 8-7: Information Exchange for Disruption Recovery - Example based on loss of runway capacity**

All of the information identified in figure 8-7 should be updated at regular intervals, or when any significant change occurs to the current status or the prediction.

Considering the example of figure 8-7, it is evident that much of the information identified is already available to AOCs today, but that additional information is required in three main areas.
The first is information about the current and expected status of the airfield and runway(s). Although meteo information is currently available to all, the assessment of what the current and forecast meteo conditions will mean in terms of airport capacity is generally not available to AOCs. Airfield/runway status, and predictions for how and when it will change, are essential for the AOC to make informed flight planning decisions.

The same general principle applies to any cause of disruption: the AOC would benefit from access to the local assessment of the effect of the basic problem—in terms of current and expected capacity of airport, terminals, ATC sectors, or whatever resources are affected.

A specific example is de-icing information. According to the de-icing procedures recently agreed by the EAMG [EAMG], an airport must publish a de-icing plan in order to be eligible for ATFM exceptions in de-icing conditions. It is proposed that this should be made available to AOCs and other actors, together with dynamic information on the current status of de-icing activities at the airport.

The second area where better information would be useful to AOCs is on the alternatives open to it. Again this is essential for informed flight planning decisions.

For the example of airport disruption, information on alternatives concerns the status of possible diversion airfields—whether they are also affected by the meteo conditions, whether they have spare capacity, what facilities are currently available, ... Where disruption is caused by a loss of ATC sector capacity, information on alternatives concerns options for re-routing to avoid disrupted areas of airspace.

Information on alternatives could come from the affected ATC unit or centrally from CFMU, depending on where the best information is available.

The third area where additional information is required by AOCs is specific to the airport-based example if figure 8-7. During a time of disruption at an airport, flights may be assigned different stands from usual, in quite different areas of the airport. Information about the assigned stand and gate, including the facilities available there and the airlines or handlers usually based in that area of the airport, should be sent to the AOC as soon as possible to assist in their operations planning. This kind of information is particularly useful if a flight has diverted to an alternate airfield from which it does not usually operate.

Delay forecasts are already available in the current system—they may be obtained from the currently-expected flow management slots for flights that are already planned to use the disrupted airport or airspace. These forecasts could be improved if traffic not yet planned, but expected, was also taken into account.

Any forecast or prediction should ideally be accompanied by an estimate of confidence to be fully useful.

8.5.2.3 Interfaces

AOCs have access to regulations and delay forecasts in the current system, via their CFMU terminals. However, the information is not presented in such a way that it is easily accessed when under pressure to resolve unexpected problems quickly. Similarly AOCs have access to meteo reports and forecasts, but these are not always rapidly-available on-line.

Automatic distribution of information to interfaces using newer display technology would allow more rapid access.

Ideally, AOCs’ (and other actors) could benefit from a “disruption-focused” display system. This is envisaged to allow all the required information associated with a current problem to be available from the same system, at the same time, and presented coherently in one easy-to-use package.
Local actors probably have the most motivation to solve local disruption problems. Therefore, initial implementations of this application can be envisaged centred around individual airports, with no change to the current CFMU involvement.

No automatic interface currently exists between individual airports (or other ATC units) and AOCs as a whole. The best way of providing this interface in the short term would need to be determined.

In the longer term, all the information identified here should be included in a shared-access, virtual (distributed) database, the “virtual information pool” as described in section 4 of the present report.

8.5.3 ATM2000+ Timescale

An initial implementation should be achievable in the near term (2000–2002) if work is initiated promptly. Making available the full range of information identified above might be a medium term goal.

8.5.4 Evaluation of Costs and Benefits

8.5.4.1 Areas of Cost and Benefit

The cost of putting in place initial implementations of the required interfaces between airports and AOCs should be small. A small amount of additional investment would be required for fuller implementations of this application, including improved displays.

Additional operating costs may arise from the need to provide in an electronic form information currently held in the Tower controller’s head.

The first beneficiaries of this application are envisaged to be the AOCs, who should be enabled to manage their schedules better in the face of unforeseen and severe losses of capacity. This should result in less disruption to schedules at the time of the problem, and quicker recovery from the disruption caused by the “crisis”.

If AOs are able to manage their schedules better to reduce the disruption and to recover more quickly, this will mean reduced disruption to flights operating to and from the affected airport. The Airport Authority concerned will benefit from reduced disruption to services at their airport.

8.5.4.2 Metrics

It will be difficult to measure objectively the success of this application in operational use, because no two “crises” are the same, so it will not be easy to compare problems before and after implementation. Fog at airports may offer the best possibility here, since at certain north European airports it occurs relatively frequently. Taking a given airport, it ought to be possible to identify a number of instances where the actual weather was similar and similar regulations were set.

Then the metrics which could be compared before and after implementation are:

- the length of time taken for affected airline’s schedules to recover;
- the total delay to all flights affected, the number of flights affected, and the average delay;
- the length of time taken for the affected airport’s schedule to recover.

Alternatively, this could be done in a simulation. Such a simulation would need to involve Airline Operations Controllers, to investigate how their operational responses to the “crisis” were altered by the ready availability of more information, and what the effect was in terms of disruption to airline schedules.
If the application were implemented at one or more individual airports, subjective assessments of the effect on “crisis” operations could be obtained from Airline, Airport and Tower ATC staff involved. This would probably be sufficient measure of the success of this simple and cheap application.

8.5.5 Dependencies
No particular dependencies have been identified, but as noted above, the accessibility of airport meteo information (METARs and TAFs) could be improved in some cases.

8.5.6 Problems and Further Studies Required
The best way of providing an automatic interface between individual airports (or other ATC units) and AOCs as a whole remains to be determined.

The required information update rate, and the requirements this implies for the communications infrastructure, should be investigated.
8.6 Disruption Recovery 2: Departures from Nearby Airfields

8.6.1 General Description

8.6.1.1 Context
The general context of disruption caused by severe and unforeseen reduction in capacity is given in section 8.5.1.1.

When there is a severe and unforeseen reduction in capacity (at an airport or in an airspace sector), it is often not possible to predict reliably how long it will persist, or how severe it will be in, say, 2 hours’ time. So the flow regulations applied are determined mainly by local experience and guesswork. The strategy usually employed is to plan conservatively (assume the worst, thus avoiding potentially dangerous overloads), then to reduce restrictions as early as possible.

This approach is safer and generally considered preferable by the airlines (it is better to expect a 2-hour delay and end up with a 1-hour delay than vice versa). However it may result in unused capacity when the capacity improves sooner than planned, and may also result in unnecessary cancellations.

8.6.1.2 Objectives and Benefits
This application aims to minimise the capacity wasted in the above circumstances, by expediting departures from nearby airports that are bound for the constraint in question (the airport or sector with severely reduced capacity).

Both the airlines and the resource provider (Airport or ATC sector) benefit from minimising wasted capacity.

There are a number of existing examples of this kind of co-operation to minimise wasted capacity. For example when there is fog at Heathrow, British Airways have their flights from Manchester standing by, ready to take off at minimum notice once RVR at Heathrow improves. There are similar examples at Schiphol and Charles de Gaulle, and at many other airports. However, these current instances of collaboration are all ad-hoc arrangements, supported principally by telephone calls.

The aim of this application is to make this kind of co-operation part of the regular Air Traffic Management process, supported by better information sharing (using automatic means where necessary).

The CFMU READY message is also used today to enable unused Flow Management slots to be filled by flights that are standing by, ready to depart. However, this mechanism does not involve the departure airports in expediting departures to assist in minimising wasted capacity at times of disruption.

8.6.1.3 Collaborative Decision Making Aspects
This application is a good example of co-operation for the benefit of all parties concerned, showing how collaborative planning and decision making can help the Air Traffic system to recover from disruption.

The collaboration suggested in this application can be broadened to the more general case of (any) arrivals constraints providing priorities to departures management. That general case of Integrated Arrivals and Departures Management is considered in section 7.5 of the present report.
8.6.2 Description of Process

8.6.2.1 Actors
To enable this kind of co-operation to occur in a systematic way, the following roles are envisaged:

- The local ATC unit would indicate that an airport or sector was disrupted, such that flights from nearby airfields destined for that resource might be cleared at short notice to depart, should “spare” capacity become available. The local ATC unit would also be responsible for flagging up when spare capacity is arising.
- The process could be administered by CFMU to ensure the opportunities for using the spare capacity are available fairly to all flights. CFMU would then be responsible for matching ready flights with spare capacity, and for notifying ATC at the departure airport. Alternatively, the local ATC unit could take on this co-ordinating role. This latter is closer to the present ad-hoc approach, and could be appropriate as an initial implementation.
- AOCs would already have access to information about the problems at the disrupted airport or sector (as described in the previous application, in section 8.5). They would be responsible for re-planning their flights as necessary, and ensuring their pilots were aware of the situation.
- Pilots would be responsible (as now) for indicating that they are ready to depart.
- Departure ATC (at the departure airports) would be responsible for prioritising the identified flights, if possible.

The interactions between these actors are illustrated in figure 8-8.


8.6.2.2 Information Flows and Processes

The information flows envisaged between actors are identified in figure 8-8.

In order to implement the proposed process as a formalised part of the Air Traffic Management system, there would need to be a protocol to ensure that the candidate flights were treated fairly, rather than one airline always having priority in case of spare capacity at a given airport or sector.

8.6.2.3 Interfaces

The existing CFMU READY message would be used by affected to indicate that they were ready to depart at minimum notice. However, in a local implementation (where CFMU is not involved as co-ordinator) another mechanism would have to be agreed.

If CFMU were involved as co-ordinator, a formal procedure would be needed for indicating that “disruption conditions” apply to a given airport or sector.

CFMU (or co-ordinating ATC unit in an initial implementation) needs to indicate to Departure ATC that a flight had been given an immediate slot to enable spare capacity to be used, and should be prioritised in the departure sequence if possible. In an initial implementation, that notification could be passed by telephone between Towers. In the longer term, an automatic notification would be required to minimise ATC workload—an “As Soon As Possible” CFMU slot message could be envisaged.
8.6.3 ATM2000+ Timescale
This application could be considered as an example of a system improvement in either the area of Integrated Arrivals and Departures Management or Improved Surface Management [ATM2000+]. It is proposed for implementation in the medium term: approximately 2003-2007.

8.6.4 Evaluation of Costs and Benefits

8.6.4.1 Areas of Cost and Benefit
A small amount of initial investment would be required to develop operational procedures and protocols. No new communications links are necessary, although it is envisaged that in the longer term, the more-efficient communications means that are required for many applications would make this application more efficient too.

Operating costs are not envisaged to be significant.

The improved disruption recovery offered by this application should benefit all actors in terms of operating efficiency.

- For ATC, and for the Airport Authority of a disrupted airport, it means improved use of available capacity (which for an Airport Authority translates into increased profit).
- For AOs and passengers of expedited flights it means reduced delays, while other flights are not adversely affected.
- It may also benefit the departure airports: the expedited aircraft may have had to bear much longer delays had their departures not been prioritised, and hence they would have blocked stands and/or apron space at the airport, contributing to congestion on the ground for much longer.

8.6.4.2 Metrics
It will be difficult to measure objectively the success of this application in operational use, because no two “crises” are the same, so it will not be easy to compare problems before and after implementation. Fog at airports may offer the best possibility here, since at certain north European airports it occurs relatively frequently. Taking a given airport, it ought to be possible to identify a number of instances where the actual weather was similar and similar regulations were set.

Then the metrics which could be compared before and after implementation are:

- the length of time taken for affected airline’s schedules to recover;
- the total delay to all flights affected, the number of flights affected, and the average delay;
- resulting financial savings for AOs;
- the length of time taken for the affected airport’s schedule to recover.

Alternatively, this could be done in a simulation. Such a simulation would need to involve Airline Operations Controllers, to investigate how their operational responses to the “crisis” were altered by the ready availability of more information, and what the effect was in terms of disruption to airline schedules.
8.6.5 Dependencies
The possibility of prioritising certain departures at the airports of departure may be required, although this may be of secondary importance. Prioritisation of departures is discussed further in the Collaborative Departures Sequencing application, section 8.4.

There is a link with arrivals management at a disrupted airport.

8.6.6 Problems and Further Studies Required
The following topics for investigation are noted:

- The scope for improvement offered by this application: How many flights would be in a position to take off and arrive at a disrupted airport or sector within 15, 30, 45, 60 ... minutes? What improvement in capacity utilisation would that number of flights represent?

- How, in an initial, local implementation (with the disrupted ATC Unit acting as co-ordinator) affected flights could efficiently inform the affected ATC Unit that they were ready to depart.

- A protocol to ensure that the candidate flights are treated fairly, rather than one airline always having priority in case of spare capacity at a given airport or sector.

It is recommended that further specific mechanisms for improving disruption by collaborative planning and decision making are investigated.
9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions
This study was established to elaborate the concept of Collaborative Decision Making and thereby to demonstrate what form it could take in the context of the European ATM Strategy for the year 2000 [ATM2000+]. The approach followed was to identify a number of potential applications. Several of the proposed applications are processes which already exist or are under development: this served to demonstrate that CDM is already widespread although it may not be specifically described as such.

These applications were developed addressing all phases of flight, from strategic planning to post-flight analysis. The primary driver of the applications was to identify a benefit that could be gained by increasing the level or the form of interaction that exists between the actors in the ATM system: ATM, airports and aircraft operators.

The proposed applications should not be regarded as a complete and definitive set, nor should they be regarded as defining CDM. Instead, CDM should be considered as a principle, and the applications should be seen as providing views to help the reader understand how the principle could be applied.

The benefits of the applications have been explored, and these are very wide and varied in nature. However, even at the most basic level of purely improving the distribution of existing amongst users it is clear that there are significant benefits, often at relatively low cost. Thus there is the potential for "quick wins" to be realised, paving the way for more general improvements requiring long term implementations.

The elaboration of the potential applications highlighted a number of common issues that will need to be considered when implementing any CDM application. These include:

- safety, liability and security;
- information management;
- architecture;
- appropriate communications technologies;
- information display and human-machine interfaces.

In all, the study team has identified and explored twenty-two potential applications of CDM ideas and principles. To provide an overview, the applications have been summarised in the tables 9-1 to 9-3 in terms of short, medium and long term based on the timescale proposed in [ATM2000+], and a summary of the potential benefits of each is provided.
Table 9-1: Applications Proposed for Implementation in the Short Term

<table>
<thead>
<tr>
<th>Applications (report section no.)</th>
<th>Potential Benefits</th>
</tr>
</thead>
</table>
| Conditional Routes in Flight Planning (5.1) | • Increased use of CDRs in flight planning  
• Reduced fuel costs  
• Capacity increase |
| Rerouting (6.4) | • Reduced ATFM delays  
• Increased flexibility for airspace users  
• Reduced likelihood of ATC sector overloads |
| Slot Swapping (6.5) | • Possibility for Aircraft Operators to prioritise flights within their own set of flights |
| Airport Information for Flight Planning (6.8) | • Minimisation of the loaded fuel  
• Improvement of the flight trajectory prediction |
| Estimation of In-Block Time (7.3) | • Improvement of the stand allocation process  
• Better utilisation of the ground facilities  
• Improved operations for the airlines  
• Shared understanding of Estimated Time of Arrival |
| Meteo Information Exchange (7.7) | • Greatly increased quantity of observations for meteo modelling and forecasting  
• Enables significant improvement in quality of meteo information available to airspace users and service providers |
| Estimation of Departure Time (8.2) | • Updated estimates of departure time for Stand Allocation, AOC, ACC  
• More effective planning of departing flights |
| Information About Disruption (8.5) | • Better-informed decisions by Aircraft Operators in cases of disruption  
• Should reduce disruption to schedules  
• Better and safer use of available ATC and Airport capacity |
### Table 9-2: Applications Proposed for Implementation in the Medium Term (approx. 2003–2007, following [ATM2000+] timescales)

<table>
<thead>
<tr>
<th>Applications (report section no.)</th>
<th>Potential Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Planning Model (6.2)</td>
<td>• Better quality predictions of traffic for ATM operations management</td>
</tr>
<tr>
<td>Substitution on Cancellation (6.6)</td>
<td>• Better use of airport capacity in situations of congestion</td>
</tr>
<tr>
<td></td>
<td>• Improved fleet management for Aircraft Operators</td>
</tr>
<tr>
<td></td>
<td>• Enhanced traffic flow management and disruption recovery</td>
</tr>
<tr>
<td>Slot Shifting (6.7)</td>
<td>• Reduction in lost ATFM slots</td>
</tr>
<tr>
<td></td>
<td>• Better use of airport ground infrastructures</td>
</tr>
<tr>
<td></td>
<td>• More flexibility for the airlines</td>
</tr>
<tr>
<td></td>
<td>• Reduced use of slot extension process</td>
</tr>
<tr>
<td>Distribution of AO/Aircraft Flight Plan Information (7.1)</td>
<td>• Updated flight plan information available</td>
</tr>
<tr>
<td></td>
<td>• Improves trajectory predictions by ATC and ATFM</td>
</tr>
<tr>
<td>Collaborative Stand and Gate Management (8.1)</td>
<td>• More efficient management of stands and gates</td>
</tr>
<tr>
<td></td>
<td>• Increased utilisation of airport resources</td>
</tr>
<tr>
<td>Estimation of Off-Block Time (8.3)</td>
<td>• Accurate estimate of Off-Blocks Time made available to all actors</td>
</tr>
<tr>
<td></td>
<td>• More effective planning of departing flights</td>
</tr>
<tr>
<td>Collaborative Departures Sequencing (8.4)</td>
<td>• Aircraft Operator and Airport priorities taken into account in departures sequence</td>
</tr>
<tr>
<td></td>
<td>• Increased flexibility and more efficient operations for Aircraft Operator</td>
</tr>
<tr>
<td></td>
<td>• Increased utilisation of airport resources</td>
</tr>
<tr>
<td>Disruption Recovery - Departures from Nearby Airfields (8.6)</td>
<td>• Better utilisation of available capacity</td>
</tr>
<tr>
<td></td>
<td>• Improved disruption recovery</td>
</tr>
</tbody>
</table>
### Table 9-3: Applications Proposed for Implementation in the Longer Term (approx. 2008–2015, following [ATM2000+] timescales)

<table>
<thead>
<tr>
<th>Applications (report section no.)</th>
<th>Potential Benefits</th>
</tr>
</thead>
</table>
| Collaborative Flow and Capacity Management (6.1) | • Optimise match between ATC capacity and traffic demand  
• Reduced ATFM delays  
• Reduced likelihood of ATC sector overloads  
• Increased flexibility for airspace users |
| Co-ordination between Airport Slot and ATFM (6.3) | • Better schedule-keeping  
• Reduced ATFM delays  
• Reduced likelihood of ATC sector overloads |
| In-Flight Traffic Management (7.2) | • Improved decision making by Aircraft Operators in the airborne phases of flight |
| Optimisation of Arrivals (7.4) | • Improved decision making by Aircraft Operators on stacked flights in holding areas  
• Improved control on changing runway configurations |
| Integrated Arrivals and Departures Management (7.5) | • Global optimisation of planning on scheduled departure and arrival times  
• Ensuring better flight efficiency by integrated arrival management  
• Optimised use of scarce arrival resources |
| Autonomous Separation in Free Flight Airspace (7.6) | • Increased flexibility and flight efficiency for Aircraft Operators  
• Reduced ATC workload |
9.2 Recommendations

At present the concept of Collaborative Decision Making identified in the ATM Strategy for 2000+ is in the process of elaboration. As demonstrated in the US, one of the strengths of the collaborative approach is that the ideas can and should be employed in many separate initiatives. This document has identified a number of applications, some of which already exist in current plans and others that are hypothetical.

In order to realise the concept at a practical level it is necessary to further develop its use within the framework of European ATM development and implementation programmes.

It is proposed that the potential applications identified in this report could be treated in a number of different ways, as follows:

- For applications that are currently under development, there is no need to take specific action, except to make clear that they are regarded as CDM activities.
- Some new applications would be best realised by introduction of their ideas within current EUROCONTROL programmes. This would apply where collaborative decision making can contribute to improving a process within the programme, for example in Arrivals Management.
- Other applications may be of sufficient scope and complexity to merit their own dedicated Eurocontrol programmes. For this, key criteria would be that the activity must be definable as a separate activity independent of other programmes and with clear deliverables and timescale. An example of such an application may be Collaborative Flow and Capacity Management.
- Lastly, other applications would be implemented through inclusion in standalone development programmes, perhaps linked to activities of individual states. This approach would apply where an application is directed at localised changes in operational procedures rather than in a European-wide initiative. For example, applications centred around airport operations may be introduced in this way.

A feasible means of carrying forward development of the applications is required.

Each of the EATCHIP work programmes should be examined to determine what collaborative aspects should be recognised and emphasised, and the applications proposed here could act as a guide for this process. Ideally, the work programmes should then be adapted to include appropriate research and development tasks.

This integration of applications within programmes runs the risk of dilution of the principles underlying this document and hence Collaborative Decision Making: it would be likely that CDM would mean something different to everyone. To counteract this, an independent line of work is required, focusing on the underlying ideas and typically performing four roles:

- providing a forum for ensuring the relevant actors (airlines etc.) are actively involved, distributing information and ideas on CDM, and seeking out new ways in which to apply the concept;
- acting as a focus for development programmes by providing assistance and feedback (for example on issues such as management of equity and cost benefit analysis) and by co-ordinating separate initiatives (for example suggesting where common facilities could be used by a number of applications, and facilitating exchange of knowledge and experience between related initiatives at separate airports or states);
- carrying out cost-benefit analyses to determine the return on investment from potential applications;
• carrying out development and trial of selected applications to act as demonstrations of what can be achieved and thereby to "spread the word", both to users and within the ATM world.

Thus the team makes three principal recommendations as a result of this study:

1. Evaluate the existing EATCHIP work programmes and incorporate the underlying ideas in appropriate programmes where appropriate.

2. Select one of the short-term applications described in this document for implementation as soon as possible in order to demonstrate the benefits of CDM at the earliest opportunity and act as a reference point.

3. Establish a project to act as "promoter of the CDM concept" to support and put in place demonstrations of the concept through development of selected trial applications.