Roadmap for the implementation of data link services in European Air Traffic Management (ATM):

Application Assessment

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1 Introduction

1.1 Purpose of this document

1.1.1 This document has been produced during Phase 1 of a study for the European Commission to develop a roadmap for the implementation of data link services supporting air traffic management (ATM) applications in Europe. The work has been carried out under contract B2001/B2 – 7020B/S12.330694.

1.1.2 This study is an independent assessment of different candidate data link technologies. It includes an evaluation of the industrial impact at a European level, with the aim of proposing the most suitable data link(s) to support the European decision-making process. To achieve this, it is necessary to establish a tentative list of ATM applications particularly suited for enhancing safety and capacity. These applications will be based on the definition of medium and long term objectives in air traffic management.

1.1.3 The purpose of this document is to list the ATM applications requiring data link support, to analyse them in compliance with agreed standards of reference and to provide an initial presentation of an ATM application timeline. The ATM applications will be listed under the operational concepts they support.

1.1.4 The ATM application timeline presented is an initial assessment of the practicality and desirability of introducing each new ATM application. In particular, a multi-criteria analysis technique has been used. This balances the key constraints that influence implementation timescales and has been applied consistently to all ATM applications to provide an overall timescale for implementation.

1.1.5 The timescales shown have taken account of:

- stakeholder views on the release 1.A of this document;
- a benefit analysis of the ATM applications.
- stakeholder views obtained during review of this release of the document, including the results of a Stakeholder workshop to be held on 3 July 2002.

1.1.6 The timescales do not take account of the data link technology analysis undertaken in Phase 2 which has resulted in a small number of changes to the timescales for some ATM applications depending on the availability of suitable data link technology.

1.2 Contents

1.2.1 This document represents the output from work package WP1140: Populate Application Assessment Framework. It contains:

- A description of the approach used in Phase 1 of the study (Section 2).
- Identified ATM applications and an initial assessment of benefits (Section 3).
- An assessment of implementation constraints and estimation of timescales for introducing each ATM application (Section 4).
- A benefit analysis of the ATM applications (Section 5).

- A summary of stakeholder opinion on the ATM applications (Section 6).
- An initial ATM application timeline (Section 7).
- Technical requirements for the selected ATM applications (Section 8).

1.2.2 Annex A provides a list of acronyms and references.

2 Phase 1 Approach

2.1 Terminology used in the study

2.1.1 Figure 2-1 illustrates the relationship between ATM applications and technical requirements:

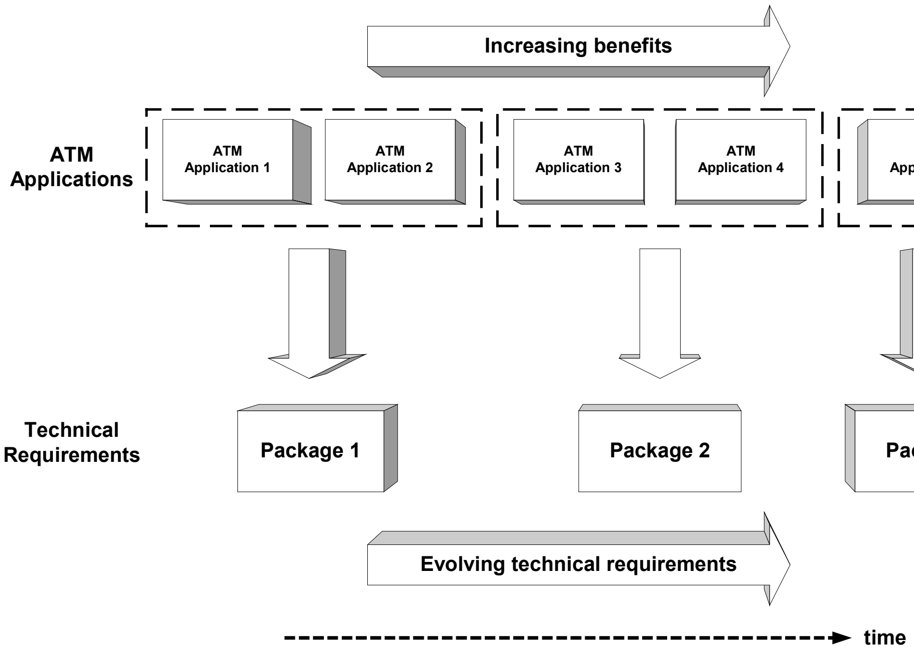

Figure 2-1: Evolution of ATM applications and technical requirements

2.1.2 The term "ATM application" is used to represent a change to the way in which air traffic management is carried out. The change might be to the control procedures, perhaps involving delegation of some tasks to the pilot, or to the way in which current services are provided, such as automating some current tasks or providing an alternative method of obtaining essential information such as a surveillance picture. Each ATM application has the potential to provide benefits in one or more airspace regions. Therefore ATM applications, and their evolution in time, will be used in the study as a focus for the assessment of benefits.

2.1.3 "Technical requirements" describe data link characteristics necessary to support the ATM applications. At a high level, these consist of the interpretation of the operational communication characteristics of ATM applications onto technical communication characteristics. At a lower level, performance requirements (range, integrity, connectivity, etc) are defined. The technical requirements, and their evolution in time, will provide the focus for the technology assessment.

2.2 Objectives of Phase 1

2.2.1 The objectives for Phase 1 of the study are to:

- identify the ATM applications that require communication services and that could be implemented within European airspace in the period up to 2015;
- assess which ATM applications offer most benefit to stakeholders;
- analyse the implementation constraints and their impact on the timescales for realisation of each ATM Application;
- select those ATM applications which provide the best balance between benefits and implementation constraints;
- propose an initial timeline for the implementation of the ATM applications;
- provide technical requirements for the data links required to support the ATM applications in the period up to 2010 taking account of the need to prepare for a later extension of the data link infrastructure in the period 2010 – 2015;
- obtain stakeholder endorsement of the selected ATM applications, the initial timeline and the technical requirements.

2.2.2 Note that a further objective of Phase 1 is to put in place the assessment framework which will be used to evaluate candidate technologies in Phase 2. This will be based on the technical requirements. It is expected that, as a result of the technology assessment, timescales for the ATM applications will need some refinement and hence there is some level of iteration between Phase 1 and Phase 2. At this stage in the project, the initial selection and timeline for ATM applications is made by focussing not on the data link technology but on the supporting ATM infrastructure.

2.2.3 In order to achieve the objectives for Phase 1, three analysis steps have been used as described below.

2.3 Step 1 analysis

2.3.1 The aim of Step 1 was to derive a complete list of ATM applications which in, the study team's view, spans all possibilities for future ATM development in the period to 2015.

2.3.2 The analysis was based on a thorough review of the literature. In order to provide a structure to this review, to ensure that all relevant ATM applications were included and to assist in the presentation of results, a top down process was used, starting at a broader level of detail than is required to define a single ATM application. This is illustrated in Figure 2-2 using the particular example of progressive delegation of responsibility to pilot[1]:

[1] Note that the particular example is illustrative and the study has considered a wider range of ATM applications than those shown in the diagram.

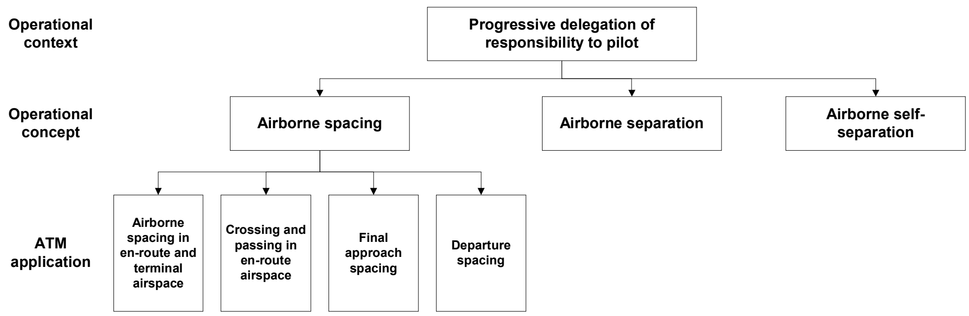

Figure 2-2: Top down process for identifying ATM applications

2.3.3 The term "operational context" defines at the highest level the potential changes to the control process that could occur in the next 15 years. The aim was to define groups of ATM applications that had important features in common and which could act as an overall framework for analysis. There are many ways of deciding on such a grouping and it is difficult to avoid overlap. However the following operational contexts were selected as most convenient by the study team and also closely related to a grouping selected as part of the Eurocontrol MACONDO study [118]:

- **Enhanced aircraft operations**, containing ATM applications which develop, but do not change radically, the current methods of air traffic control.
- **Enhanced airspace organisation and management**, representing changes in airspace and route structure design and flexible use of airspace.
- **Progressive delegation of responsibility to pilot**, representing ATM applications which cause a significant change to the manner in which aircraft are currently controlled.
- **Enhanced airport surface services**, containing ATM applications relevant to airports which are not included in other operational contexts.
- **Enhanced services to remote and oceanic areas**, containing ATM applications relevant to remote and oceanic areas which are not included in other operational contexts.

2.3.4 For each operational context, a number of individual operational concepts were identified which represent distinct groups of ATM applications. The key aim of this part of the work was to ensure that the full range of operational concepts currently being considered by the aviation community was captured within the study. Taking the example shown in Figure 2-2 for the operational context "progressive delegation of responsibility to pilot", there are a number of distinct operational concepts which are differentiated according to the level of separation responsibility delegated to the pilot: airborne spacing, airborne separation and airborne self-separation.

2.3.5 The operational concepts do not provide enough detail to establish benefits or derive technical requirements and a further stage of analysis was carried out to derive a list of ATM applications belonging to the same operational concept. These ATM applications provide specific examples of the operational concept based on, for example, phase of flight or airspace type. For example, the airborne spacing operational concept, illustrated in Figure 2-2, includes specific

ATM applications for the departure, terminal and en-route, and arrival phases of flight.

2.3.6 Through literature review, the study team carried out a characterisation of each ATM application in terms of the expected dependence on data link and the possible benefits Detailed technical requirements will be derived in Step 3 of Phase 1 of the project.

2.3.7 The study team also carried out an analysis of the complexity of each ATM application which identified the main implementation constraints and leads to an assessment of timescales for introducing the ATM applications. As a result, an initial grouping of ATM applications into a time sequence was carried out as illustrated in Figure 2-3.

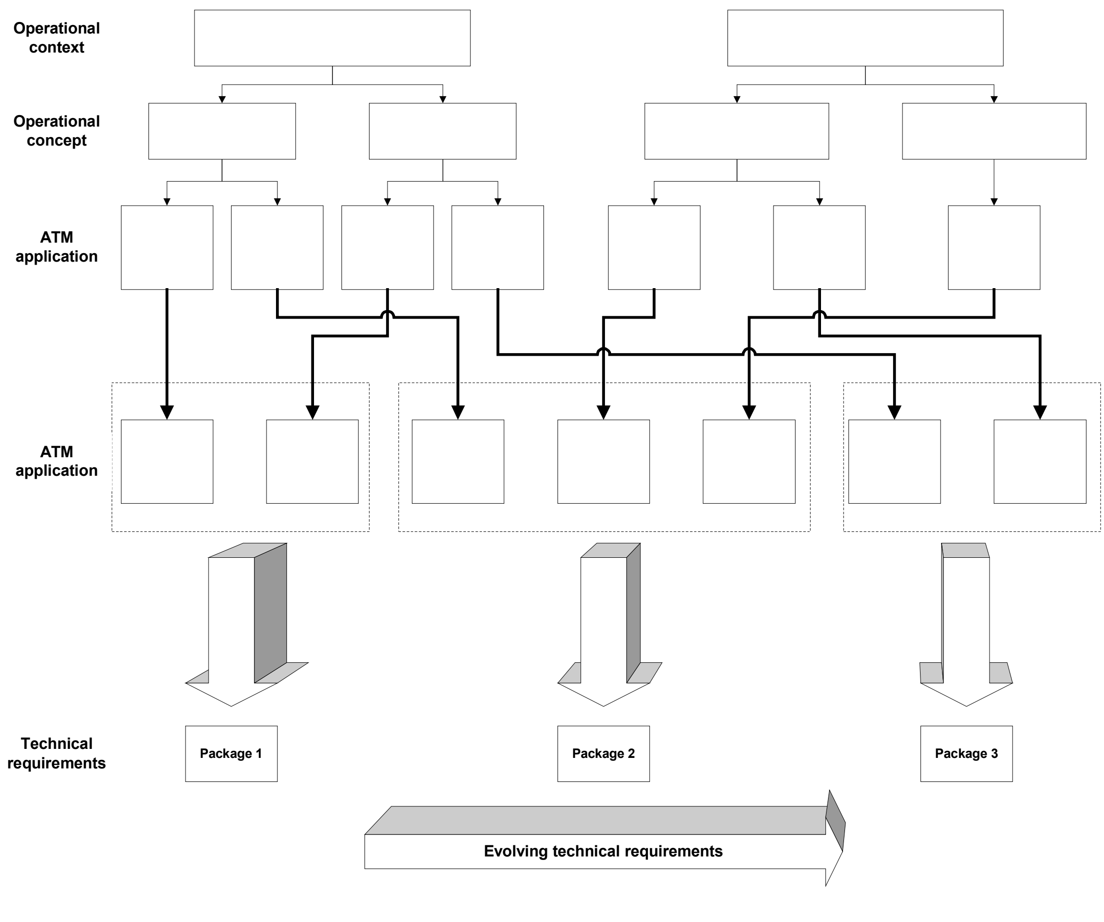
Operational context
Operational concept
ATM application
ATM application
Technical requirements
Package 1
Package 2
Package 3
Evolving technical requirements

Figure 2-3: Grouping of ATM applications into a time sequence

2.3.8 Step 1 therefore results in a proposed list of ATM applications for further analysis together with a timeline based on the analysis of implementation constraints.

2.3.9 The results of Step 1 have been reviewed by the Peer Review Group. The results are summarised in Section 6. At the time of this issue of the document, not all of the Peer Review Group have had time to respond. However, the comments received so far broadly endorse the identification of ATM applications and initial timescales.

2.4 Step 2 analysis

2.4.1 Step 2 has consisted of providing a response to the comments by the Peer Review Group on the Step 1 results, deriving an initial set of technical requirements for the ATM applications and providing a benefit analysis. The approach to the derivation of technical requirements is set out in Section 8.

2.4.2 The results of Step 2 have been used to prioritise the ATM applications and to refine the timeline.

2.4.3 The results of Step 2 will be reviewed by the Peer Review Group to obtain endorsement of the second stage analysis. This review cycle will culminate in a Stakeholder workshop to obtain Stakeholder comment and to complete the ATM application timeline.

2.5 Step 3 analysis

2.5.1 A final stage of analysis will be carried out to derive a technology assessment framework based on the ATM applications identified in Phase 1 and including detailed technical requirements for the selected ATM applications. This will be used as part of the assessment framework for Phase 2.

3 ATM Application identification

3.1 Introduction

3.1.1 This section lists the identified ATM applications and presents the results of an initial benefit analysis. An ATM application is included in this section if it has the potential to offer benefit to European aviation within the period to 2015 and is being considered by at least part of the aviation community. It is also important that the choice of ATM application is interoperable with choices made in other regions.

3.1.2 The benefit analysis at this stage of the work was not intended to provide quantitative levels of benefit. Instead, each ATM Application was assessed against a number of criteria with the assessment levels defined in Table 3-1.

Small	Medium	Large
Capacity		
small (eg controller workload reduction 0 - 5%, or 0 - 1 extra slot)	medium (eg controller workload reduction 5 – 10% or 1 - 3 extra slots)	high (eg controller workload reduction 10 - 15% or greater than 3 extra slots)
Safety		
low (eg enhancement in Visual Meteorological Conditions (VMC)	medium (eg significant reduction of incident rate)	high (eg substantial reduction of incident rate)
Flight efficiency		
low (eg supports small reduction in delays or route length)	medium (eg supports significant reduction in delays or route length)	high (eg supports substantial reduction in delays or route length)
Cost Effectiveness		
low (eg small reduction in ATS costs)	medium (eg significant reduction in ATS costs)	high (eg substantial reduction in ATS costs)
Environmental impact		
low (eg small reduction in fuel usage, or noise profiles)	medium (eg significant reduction in fuel usage, or noise profiles)	high (eg substantial reduction in fuel usage, or noise profiles)
Enabler and other benefits		
low (eg small contribution to confidence building for later ATM applications)	medium (eg significant contribution to confidence building for later ATM applications)	high (eg substantial contribution to confidence building for later ATM applications)

Table 3-1: Assessment levels for benefit analysis

3.1.3 Note that, at this stage in the analysis, the benefit “cost effectiveness” is used to identify a general potential for general cost savings. This includes:

- the potential for a reduction in the number of sectors, leading to, for example, reduced staff costs;
- an alternative, potentially lower cost, means for providing essential ground infrastructure.

The potential cost reduction needs to be set against the implementation costs. Detailed evaluation of this will be carried out in Phase 2 of the study.

3.1.4 The relevance of each ATM application to the objectives within the Eurocontrol Operational Concept Document (OCD) was also recorded.

3.1.5 Note that the terms of reference of the study deals with identification of ATM applications which may require a data link. Therefore the focus is on air/ground and air/air ATM applications and therefore ground-ground applications such as collaborative decision making (CDM) have not been considered.

3.1.6 Figure 3-1 summarises the operational context, operational concepts and ATM applications identified in the study.

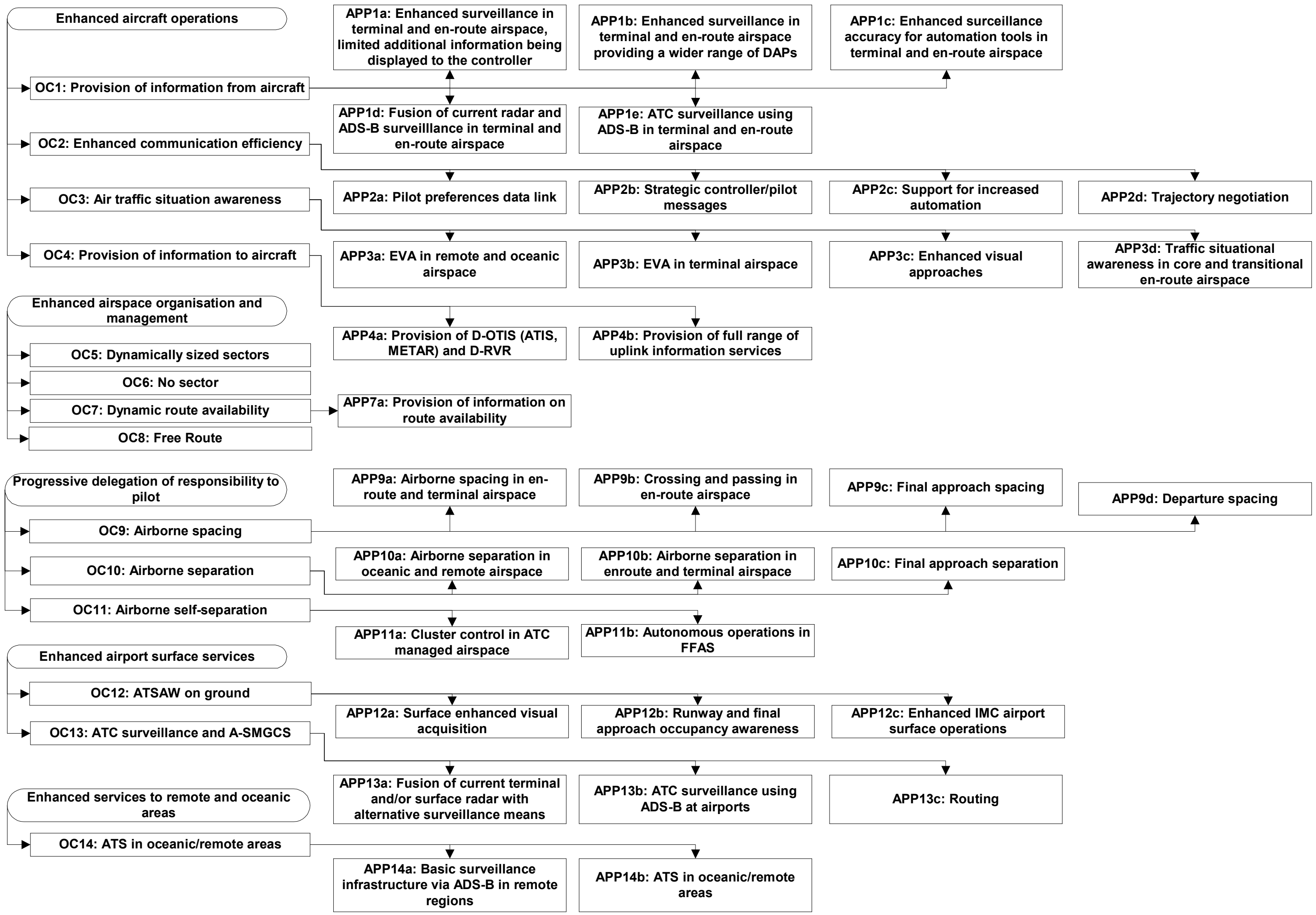

Figure 3-1: Summary of operational contexts, operational concepts and ATM application identified in the study

3.1.7 The following sections present the ATM applications which have been identified. They are grouped by operational context and operational concepts.

3.2 Enhanced aircraft operations

3.2.1 Description of operational context

3.2.1.1 Enhanced aircraft operations involve the progressive automation and optimisation of the existing "control paradigm" by introducing measures that lead to improved efficiency of the current operations without significantly changing the manner in which aircraft are controlled.

3.2.1.2 The identified operational concepts are:

- OC1[2]: Provision of information from aircraft (including improved surveillance and downlinked aircraft data).
- OC2: Enhanced communication efficiency.
- OC3: Air traffic situation awareness (ATSAW).
- OC4: Provision of information to aircraft (eg flight information services).

3.2.1.3 Note that many of the technology options relevant to this operational concept are likely to act as enablers for other ATM applications and to provide a means of gaining confidence for more challenging operational concepts[3].

3.2.2 OC1: Provision of information from aircraft

Description

3.2.2.1 Possible reasons to provide airborne data to the ground system include:

- providing basic surveillance data, including the use of alternative technology to secondary surveillance radar, to achieve multiple surveillance coverage (eg via an automatic dependent surveillance-broadcast (ADS-B) system);
- providing additional surveillance data such as downlink airborne parameters (DAP) to improve the quality of information on aircraft position and intent displayed to the controller;
- providing additional data to enhance ground systems functions (e.g. arrival managers, safety nets (short term conflict alert (STCA), Minimum Safe Altitude Warning (MSAW)), medium term conflict detection (MTCD) tools.
-

Wind information which could be of high benefit in particular for wake avoidance and reduced wake separation applications and to improve the quality of ground weather forecasts.

Identified ATM applications

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[2] Operational concepts are labelled "OCx" to assist in referring to them later in the document

[3] For example, ATSAW makes it possible to evaluate ADS-B technology and to development and trial new procedures prior to the introduction of spacing ATM applications.

3.2.2.2 This operational concept includes a range of possible ATM applications with two broad objectives:

- supplementing the data that a controller currently receives as part of the surveillance service. Such data could be provided by extension of the current radar services or by an alternative approach such as broadcast of position information.
- providing an alternative to the current surveillance infrastructure for example by supplementing radar data with ADS-B data or providing ADS-B as the only means of surveillance in some areas.

3.2.2.3 To represent these two foci, the following ATM applications have been identified.

Supplementing current surveillance data

3.2.2.4 **APP1a[4]: Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller.** This ATM application has been selected to map closely with the proposals for an initial package of 3 controller access parameters (CAPs)

3.2.2.5 **APP1b: Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs.** Provision of downlinked data to increase the efficiency for tactically separating aircraft.

3.2.2.6 **APP1c: Enhanced surveillance accuracy for automation tools in terminal and en-route airspace.** This ATM application covers the system wide use of DAPs.

Providing alternative surveillance data

3.2.2.7 **APP1d: Fusion of current radar and ADS-B surveillance in terminal and en-route airspace.** The purpose of this ATM application is to provide a means for achieving multiple coverage in an environment where radar is mixed with ADS-B surveillance. The scope of APP1d is limited to terminal and en-route regions. Provision of surveillance coverage by a similar means in the airport environment is covered by APP13a. This ATM application is not judged to be relevant to remote regions where there is unlikely to be any radar coverage.

3.2.2.8 **APP1e: Air traffic control (ATC) surveillance using ADS-B in terminal and en-route airspace.** The purpose of this ATM application is to provide surveillance coverage by ADS-B technology alone. The scope of APP1e is limited to terminal and en-route regions. Provision of surveillance coverage by a similar means in airport and remote regions is covered by APP13b and APP14a respectively.

Expected dependence on data link

3.2.2.9 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

[4] Each ATM application has been given a unique reference number, APPnx, to facilitate later reference

- aircraft to ground[5] broadcast data link: An integral part of APP1d and APP1e and an alternative to radar for APP1a, APP1b and APP1c.
- secondary surveillance radar: Assumed part of APP1d and offering an alternative to aircraft to ground broadcast for APP1a, APP1b and APP1c.
- Ground to aircraft broadcast data link: For applications APP1d and APP1e to broadcast GNSS Augmentation at least for high latitudes and for TIS-B during that transition to full ADS-B equipage.

[5] It has been noted that this term is not consistent with terminology typically used in the US. In this study, applications, which use “Aircraft to Aircraft Data communication” over a “Broadcast Data link”, the dependence on data link, will bee referred to as Aircraft to Aircraft broadcast data link. The same applies for Aircraft to Ground. This is done to stress the nature of the application in terms of data flow.

Summary of benefits for APP1a to APP1c

OC1: Provision of information from aircraft [APP1a to APP1c]

Key		
	APP1a	Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller.
	APP1b	Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs.
	APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace.

References	Enhanced surveillance cost benefit analysis (CBA) [22], Datalinking of Aircraft – Derived Information (DADI) project and Co-operative ATS (COOPATS) ATM application [39].
Compliance with OCD	Greater use of computer support tools to reduce ATC workload.

Capacity	APP1a	APP1b	APP1c
	Small	Small	Small

Capacity benefits result because of a reduction of radio telephony (R/T) communications (ie automatic confirmation of eg selected heading), a reduction in uncertainty concerning expected behaviour and more anticipation in planning traffic.

Controller support tools become more reliable (better flight profile using information from onboard systems).

In terminal area, benefits include: more precise separation spacing for wake vortex in terminal airspace.

The capacity benefits for APP1a may be derived from the enhanced surveillance CBA [22] which estimates the benefits associated with Mode S elementary surveillance based on 3 CAPS only. There is an estimated 5% increase in en-route airspace capacity. The results for the terminal area are currently being finalised. These could result in more than 5% but there is little evidence for this at present.

Downlink of other DAPS (APP1b) may bring more benefit but may also overload the controller. It is though a local issue which parameters will be displayed to (and could overload-) the controller.

Note that the airline community has yet to be convinced of the benefits and some perceive the benefits of APP1a and APP1b as zero although it is acknowledged that there may be enabling benefits for other ATM applications.

Safety	APP1a	APP1b	APP1c
	Small	Small	Small

Leads to an increase in safety by provision of more precise information making it possible to enhance tracking and safety net tools. For example the UK propose using downlinked data to reduce false alarms from safety monitoring systems resulting from perceived level busts.

Downlinked information facilitates priority, special handling or declaring an emergency.

In terminal area, benefits include conformance monitoring during simultaneous parallel and converging approaches. For example, France intends to use heading information on parallel approaches.

Flight efficiency	APP1a	APP1b	APP1c
	None	None	Small

APP1c: Improvement of efficiency is made possible by allowing for more anticipation in traffic planning.

Cost effectiveness	APP1a	APP1b	APP1c
	None	None	None

This ATM application may reduce costs associated with tracker systems but this benefit is expected to be small.

Environmental impact	APP1a	APP1b	APP1c
	None	None	None

None identified.

Enabler and other benefits	APP1a	APP1b	APP1c
	Small	Small	Small

Allows the validation of the use of DAP on the ground by testing the impact of downlinked parameters on ground systems: (IATA's view is that this may be better achieved through ADS-B) .

Support of other ATM applications relying on the use of advanced automated controller tools (e.g. Arrivals Manager (AMAN), Departure Manager (DMAN), MTCD, CDM, Surface Management) that are improved using additional aircraft data.

Possible enabler for free route operations (see OC8).

Summary of benefits for APP1d to APP1e

<table>
<tr><th colspan="4">OC1: Provision of information from aircraft [APP1d to APP1e]</th></tr>
<tr><td rowspan="2">Key</td><td>APP1d</td><td colspan="2">APP1d: Fusion of current radar and ADS-B surveillance in terminal and en-route airspace.</td></tr>
<tr><td>APP1e</td><td colspan="2">APP1e: ATC surveillance using ADS-B in terminal and en-route airspace.</td></tr>
<tr><td colspan="2">References</td><td colspan="2">The ADS-B CBA which provides benefits for air/ground enhanced surveillance in en-route managed airspace and low density airspace [38].</td></tr>
<tr><td colspan="2">Compliance with OCD</td><td colspan="2">None identified.</td></tr>
<tr><td colspan="2" rowspan="2">Capacity</td><td>APP1d</td><td>APP1e</td></tr>
<tr><td>Medium</td><td>Medium</td></tr>
<tr><td colspan="4">Application of “radar” separation standards leading to increased capacity in regions where there is no current, or insufficient, coverage.

Note that the ATM application and technology developments necessary to support APP1d and APP1e could also provide support for ATM applications APP1a to APP1c and deliver the same benefits as APP1a to APP1c.</td></tr>
<tr><td colspan="2" rowspan="2">Safety</td><td>APP1d</td><td>APP1e</td></tr>
<tr><td>None</td><td>Small</td></tr>
<tr><td colspan="4">In areas where there is currently no surveillance coverage, increased awareness of traffic. APP1d: most of core area already has radar coverage and hence this is not seen as a main benefit – maybe some benefit in transition region. Note also that this is a more significant benefit in remote regions and some airport regions and is covered in OC13 and OC14.

Increased safety where a greater level of coverage is provided. Note that this multiple coverage makes possible the safe application of reduced separation standards and hence multiple coverage is not considered a significant safety benefit in its own right.</td></tr>
<tr><td colspan="2" rowspan="2">Flight efficiency</td><td>APP1d</td><td>APP1e</td></tr>
<tr><td>None</td><td>None</td></tr>
<tr><td colspan="4">None identified.</td></tr>
<tr><td colspan="2" rowspan="2">Cost effectiveness</td><td>APP1d</td><td>APP1e</td></tr>
<tr><td>Small</td><td>Medium</td></tr>
<tr><td colspan="4">Reduction of infrastructure costs if additional surveillance coverage is provided by a means (ie ADS-B) that requires less investment cost than eg radar cover. This benefit applies both where additional cover is being provided and where existing infrastructure is being replaced. (APP1d and APP1e). APP1e likely to be most beneficial in transition regions where there is little or no current radar coverage. Stakeholders have commented that it is unlikely that APP1e would be feasible in high density terminal areas, where there will still be a need for a radar.

The ADS CBA [38] claims the benefit of gap filling for radar coverage with ADS and providing of coverage at a lower cost. It is also claimed as a technical benefit. No actual benefit 'cost' was presented. It was noted that "If it is assumed that full coverage in these remote areas has to be provided in any case, the implementation of ADS could lead to cost saving benefits in comparison to the alternative of radar installations".

Reduced disruption during planned maintenance of surveillance infrastructure because of the existence of multiple coverage (APP1d). Additional coverage would also mitigate against the unplanned outages which are unpredictable by nature and difficult to cost.</td></tr>
<tr><td colspan="2" rowspan="2">Environmental impact</td><td>APP1d</td><td>APP1e</td></tr>
<tr><td>None</td><td>None</td></tr>
<tr><td colspan="4">None identified.</td></tr>
<tr><td colspan="2" rowspan="2">Enabler and other benefits</td><td>APP1d</td><td>APP1e</td></tr>
<tr><td>None</td><td>None</td></tr>
<tr><td colspan="4">None identified.</td></tr>
</table>

3.2.3 OC2: Enhanced communication efficiency

Description

3.2.3.1 This operational concept uses data link services to improve the efficiency of communications (eg routine and strategic communication) between controllers and pilots by supplementing voice communications. It includes:

- Basic data link communications: capabilities provided to the controller to issue standard current ATS instructions/clearances and ATC information (e.g. vertical clearances, route changes, speed assignment, departure clearance), to the pilot to assist him in requesting information, to both of them to support communication management, automatic transfer of communications (which are time and channel load consuming) and flight plan consistency.
- Advanced communications: Complex clearance delivery services supporting limited re-routing, trajectory negotiation (i.e. ability to respond to limited requests for re-routing eg to avoid meteorological (MET) hazards), conflict free trajectory negotiations.
- ATCO provision with airborne information not available in the filed flight plan but helpful for the controller and pilot requests for modification of flight plan elements according to its preferences.

3.2.3.2 Note that this ATM application does not include pilot/pilot or pilot/controller communication supporting airborne spacing, separation and self-separation operational concepts which are covered in OC9, OC10 and OC11 respectively.

Identified ATM applications

3.2.3.3 The ATM applications associated with this operational concept are:

- **APP2a: Pilot preferences data link.** Downlink of a pilot's preferred routing.
- **APP2b: Strategic controller/pilot messages.** This includes downstream clearances for oceanic, information on Standard Arrivals (STARS), and strategic clearances using the CPDLC data link application.
- **APP2c: Support for increased automation.** This provides a full range of data link services which provide increased automation. In particular, this includes strategic ATM exchanges such as strategic collaborative flight plan exchanges relying on data link services such as FLIPCY and DYNAV.
- **APP2d: Trajectory negotiation.** This provides strategic ATM exchanges such as tactical collaborative flight plan exchanges relying on COTRAC data link services.

3.2.3.4 The ATM applications are expected to focus initially on core en-route and terminal regions and major airports with a later extension to transition and remote airspace.

Expected dependence on data link

3.2.3.5 It is expected that an aircraft/ground point to point data link will be required to support this operational concept in addition to current infrastructure. For application APP2d an additional Aircraft/Aircraft and point to point capability might be needed depending on the finally agreed technical procedures.

Summary of benefits

OC2: Enhanced communication efficiency

Key		
	APP2a	APP2a: Pilot preferences data link.
	APP2b	APP2b: Strategic controller/pilot messages.
	APP2c	APP2c: Support for increased automation.
	APP2d	APP2d: Trajectory negotiation.

References	Pre-Operational EUROCONTROL Trial of Air/Ground Datalink (PETAL) /LINK 2000+ [20] and ODIAC [97].
Compliance with OCD	Increasing use of free-routes and user-preferred trajectories (delivery of direct routings in less busy areas). Greater use of computer support tools to reduce ATC and cockpit workload.

Capacity	APP2a	APP2b	APP2c	APP2d
	Small	Medium	Medium	Large

Leads to an increase of controller productivity and efficiency through a reduction of R/T workload and hence leads to an increase in capacity and a reduction in delays. The key workload reducing steps are:

- Automation of controller/pilot dialogue eg clearance delivery via data link (APP2b and APP2c);
- Support for more complex clearances (APP2c);
- 4D Trajectory Negotiation supporting User Preferred Trajectories (APP2d);
- Delivery of 'Conflict Free Trajectories' (APP2d) (substantial reduction in conflict resolution workload).

LINK 2000+ simulations [20] have shown that that sector capacity increases will be:.

3 - 4% for 25% data-link equipage; 8% for 50% data-link equipage; 11% for 75% data link equipage.

Safety	APP2a	APP2b	APP2c	APP2d
	None	Medium	Medium	Medium

Lesser risk of misunderstanding between controllers and pilots. This is particularly relevant to non-core regions where there are problems with understanding of English. Benefit increases as the level of automation increases. There is already evidence that incidents have been avoided through the use of data link.

Conformance monitoring between the route flown by the pilot and the flight plan held by the flight data processing (FDP) system.

Flight efficiency	APP2a	APP2b	APP2c	APP2d
	Small	Small	Small	Large

APP2a facilitates the request for user preferred trajectories.

APP2d leads to an increase of flight efficiency due better integration by the controller of the pilot preferences.

More generally, this group of ATM applications has the potential to improve the level of service provided to aircraft as a result of a reduction of controller workload.

In the longer term, trajectory negotiation and the delivery of conflict free trajectories (APP2d) will support availability of user preferred trajectories.

Cost effectiveness	APP2a	APP2b	APP2c	APP2d
	None	None	None	None

No benefits identified.

Environmental impact	APP2a	APP2b	APP2c	APP2d
	Small	None	Small	Small

Environmental benefits result from fuel saving as aircraft receive a higher proportion of user preferred trajectories.

Enabler and other benefits	APP2a	APP2b	APP2c	APP2d
	None	Medium	Small	None

APP2b and APP2c provide opportunities to assess the impact of controller/pilot data link on the efficiency of operations and provides a means of gaining confidence prior to introduction of greater automation.

Possible enabler for free route operations (see OC8).

3.2.4 OC3: Air traffic situation awareness (ATSAW)

Description

3.2.4.1 Air traffic situation awareness enhances the flight-crew knowledge of surrounding traffic in the air [116] through the use of, for example, ADS-B and traffic information services-broadcast (TIS-B) services and a cockpit display of information (CDTI). No change in separation responsibility is provided by this ATM application and the main impact is enhancement of visual operations.

Identified ATM applications

3.2.4.2 This operational concept applies to all airspace. To analyse the operational concept, the regions of applicability has been split into three airspace regions: remote and oceanic, terminal, and core and transitional en-route. The following ATM applications have therefore been identified:

- **APP3a: Enhanced visual acquisition (EVA) in remote and oceanic airspace.**
- **APP3b: Enhanced visual acquisition (EVA) in terminal airspace.**
- **APP3c: Enhanced visual approaches.**
- **APP3d: Traffic situational awareness in core and transitional en-route airspace.** This includes a package of ATM applications: EVA, Enhanced Traffic Information Broadcast (E-TIBA) and Enhanced See and Avoid (E-S&A).

3.2.4.3 Note that EVA on the airport surface is covered under APP12a.

Expected dependence on data link

3.2.4.4 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- ground to aircraft broadcast data link: Depends on technology approach used (see paragraph 3.2.4.5):
- aircraft to aircraft broadcast data link

3.2.4.5 The requirement for a ground to aircraft broadcast data link will depend on the technology approach:

- ADS-B only in which case no uplink broadcast is required but it is to be expected that a higher level of ADS-B equipage is required to achieve benefits.
- a mixed ADS-B/TIS-B solution which has the advantage of allowing ADS-B equipped aircraft to obtain a complete aircraft picture but has the disadvantage of requiring a TIS-B network.

At this stage in the study, it is assumed that operational concepts which rely on ADS-B in core or transition regions will initially require TIS-B support for gap filling whereas in Oceanic and remote regions, it is assumed that ADS-B only solutions are provided. This assumption will be revisited during Phase 2.

Summary of benefits

OC3: Air traffic situation awareness (ATSAW)					
Key	**APP3a**	APP3a: Enhanced visual acquisition (EVA) in remote and oceanic airspace.			
	APP3b	APP3b: Enhanced visual acquisition (EVA) in terminal airspace.			
	APP3c	APP3c: Enhanced visual approaches.			
	APP3d	APP3d: Traffic situational awareness in core and transitional en-route airspace.			
References	Action Plan 1: Airborne Separation Assurance System (PO-ASAS) [116], COOPATS [39], Mediterranean Free Flight (MFF) programme: E-TIBA, Enhanced traffic information [108], NEAN update programme (NUP): EVA, Enhanced visual acquisition for see and avoid [109] and More Autonomous Aircraft in the Future ATM System (MA-AFAS) programme: enhanced situation awareness [110].				
Compliance with OCD	Improved cockpit awareness of the surrounding traffic situation.				
Capacity		**APP3a**	**APP3b**	**APP3c**	**APP3d**
		None	Small	Small	None
APP3b: EVA will provide [115] increased traffic flow under marginal VMC conditions (low sun, haze). It is estimated in [115] that EVA will provide 1-3 additional landings per hour in VMC. Enhanced visual approaches (APP3c) will make possible more optimum aircraft operation through a reduction of separation between aircraft allowing operations very close to current separation limits. Reduction in controller's workload: fewer and shorter traffic information messages because pilot has a better view of surroundings.					
Safety		**APP3a**	**APP3b**	**APP3c**	**APP3d**
		Small	Small	Small	Small
ATSAW leads to an increase in safety levels by: supporting positive identification of traffic, reducing mis-identification of aircraft and earlier anticipation of collision risks. The benefits are most effective in high traffic density complex areas or where the quality of ATS is poor (ie lack of ground surveillance). Enhanced visual acquisition is expected to provide [115] better establishment of visual contact and positive identification of aircraft, even if more than one aircraft is visible, reduced time to establish visual contact to other aircraft, improved crew capability of assessing the distance to a preceding aircraft and for keeping a certain distance from it, even at changing speed and/or heading, reduced probability of a go-around for parallel approaches (loss of visual contact) and repeated positive identification of the target in high traffic density conditions.					
Flight efficiency		**APP3a**	**APP3b**	**APP3c**	**APP3d**
		None	None	Small	None
ATSAW will provide more optimum aircraft operation, in particular using enhanced visual approaches where the maintenance of visual separation is facilitated and less speed changes are required. APP3c: Enhanced visual approaches are also expected to reduce the probability of go-arounds for parallel approaches.					
Cost effectiveness		**APP3a**	**APP3b**	**APP3c**	**APP3d**
		None	None	None	None
None identified.					
Environmental impact		**APP3a**	**APP3b**	**APP3c**	**APP3d**
		None	None	None	None
None identified.					
Enabler and other benefits		**APP3a**	**APP3b**	**APP3c**	**APP3d**
		Small	Small	Small	Small
This application is considered as a first step toward future airborne spacing, separation and self-separation applications and therefore as an "enabler" for these applications. Enabler for ATM applications where use of air/ground data link leads to concerns about loss of party line.					

3.2.5 OC4: Provision of information to aircraft

Description

3.2.5.1 Provision of ground information to aircraft includes data link operational terminal information (D-OTIS), data link runway visual range (D-RVR), data link significant meteorological information (D-SIGMET) and Notification to Air Men (NOTAM) services.

Identified ATM applications

3.2.5.2 The ATM applications associated with this operational concept are:

- **APP4a: Provision of D-OTIS (automatic terminal information service (ATIS), Meteorological Report (METAR) and D-RVR.** This ATM Application concerns automation of services that are currently delivered by voice[6].
- **APP4b: Provision of full range of uplink information services.** This provides services that are not currently available to the pilot and includes automatic Operation Flight Information Service (OFIS), which will be derived from NOTAM/ Snow Alert (SNOWTAMS) information, SIGMET.

3.2.5.3 The ATM applications are expected to focus initially on core en-route and terminal regions and major airports with a later extension to transition and remote airspace.

Expected dependence on data link

3.2.5.4 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- aircraft/ground point to point data link;
- ground to aircraft broadcast data link: provides an alternative means of delivering some or all of the required information.

[6] Some parts of this ATM Application have already been implemented like D-ATIS over ACARS.

Summary of benefits

OC4: Provision of information to aircraft			
Key	**APP4a**	APP4a: Provision of D-OTIS (ATIS, METAR) and D-RVR.	
	APP4b	APP4b: Provision of full range of uplink information services.	
References	COOPATS [39], ODIAC [97] and LINK2000+ (D-ATIS services) [20].		
Compliance with OCD	More integrated planning between ATM, aircraft operators and airports Greater use of computer support tools to reduce ATC workload.		
Capacity		**APP4a**	**APP4b**
		Small	Small
Reduction of controller and pilot R/T workload by automated delivery of flight information data. Provision of information on alternative routes to avoid congested areas.			
Safety		**APP4a**	**APP4b**
		Small	Small
Increase in safety by helping the pilot to take appropriate decisions concerning the conduct of the flight (ODIAC [97]). Increase in safety by reducing the risk in misinterpretation of the information. These benefits are not expected to be significant.			
Flight efficiency		**APP4a**	**APP4b**
		Small	Small
Enhanced flight planning and therefore flight efficiency by helping the pilot to take appropriate decisions concerning the conduct of the flight (ODIAC [97]).			
Cost effectiveness		**APP4a**	**APP4b**
Particularly for the Airlines by using D-ATIS instead of ACARS and save comm.. charges. Broadcast of RVR and braking action can minimise holding times.			
Environmental impact		**APP4a**	**APP4b**
		Small	Small
Greater availability of fuel efficient routes.			
Enabler and other benefits		**APP4a**	**APP4b**
		Small	Small
Potential to reduce congestion on voice channels. Enabler for the Dynamic route Availability operational concept (see OC7). Some pilots find benefit in point-to-point (long range) availability of D-ATIS, i.e. to request weather information as often as five times within a Flight.			

3.3 Enhanced airspace organisation and management

3.3.1 Description of operational context

3.3.1.1 Enhanced airspace organisation and management will make it possible to provide flexible planning of sectors and routes offering airspace users greater route flexibility and improving the efficiency of air traffic control. This operational concept depends mainly on re-organisation of the ground infrastructure to facilitate greater flexibility in airspace usage and route utilisation. The study focuses only on those elements which may require a data link.

3.3.1.2 The identified operational concepts are:

- OC5: Dynamically sized sectors

- OC6: No sector
- OC7: Dynamic route availability
- OC8: Free route

3.3.2 OC5: Dynamically sized sectors

Description

3.3.2.1 Airspace Sectors boundaries are adjusted to particular flows and peaks in demand in real time without constraint by national boundaries. No requirement for data link has been identified and hence this operational concept is not considered further.

3.3.3 OC6: No sector

Description

3.3.3.1 Flight by flight basis control / intent – based. This is viewed as a long term operational concept and not applicable during the timescales considered by the study. Hence this operational concept is not considered further.

3.3.4 OC7: Dynamic route availability

Description

3.3.4.1 This operational concept provides a pre-defined dynamic route network with route activation adjusted to particular flows and peaks in demand either strategically or in real time (tactical).

Identified ATM applications

3.3.4.2 The single ATM application has been identified for this operational concept:

- **APP7a: Provision of information on route availability (DYNAV)**. In addition to an uplink of information on available routes, it is expected that this ATM application will require at least part of the services provided for the PPD ATM application in order to provide efficient coordination with ground systems.

Expected dependence on data link

3.3.4.3 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- aircraft/ground point to point data link.
- ground to aircraft broadcast data link: Provides an alternative means of delivering some or all of the required information.

Summary of benefits

OC7: Dynamic route availability		
Key	**APP7a**	Provision of information on route availability (DYNAV).
References		COOPATS [39] and ODIAC [97] which state that the initial DYNAV (dynamic route availability) proposal from ground systems will be up-linked to the cockpit.
Compliance with OCD		More dynamic and flexible use of airspace. Increasing use of free-routes and user-preferred trajectories. Greater use of computer support tools to reduce ATC and cockpit workload.
Capacity		**APP7a** Small
Increase in sector efficiency and capacity through reduction in sector complexity and controller workload. Sectorisation can be tailored to accommodate traffic flow variations to take advantage of released airspace and to satisfy operational needs. Reduction in controller workload through dynamic optimisation of traffic flows and through a reduction in R/T workload.		
Safety		**APP7a** None
None identified.		
Flight efficiency		**APP7a** Medium
Increased availability of shorter routes. Enhanced flow management. Benefits can be obtained from the involvement of the Airline Operators in the negotiation of alternative routings.		
Cost effectiveness		**APP7a** None
None identified.		
Environmental impact		**APP7a** Small
More effective flight routes leading to reduced fuel burn.		
Enabler and other benefits		**APP7a** Small
COOPATS [39] concluded that: “Increased route flexibility, allied to the delegation of separation responsibilities to the cockpit, will eventually lead to the introduction of designated free-flight airspace, where aircraft will fly fuel-efficient user preferred trajectories”. Hence this is an enabler for other operational concepts such as airborne self-separation and eventually Free Flight. It is also an important enabling step for Flexible Use of Airspace (FUA).		

3.3.5 OC8: Free Route

Description

3.3.5.1 Aircraft operators file a flight plan defining the route extremity points for user-preferred routes.

3.3.5.2 The current plans for a first stage implementation do not require a data link although they may require controller tools like MTCD and conflict resolution advisor, which would benefit from aircraft intent data.

3.3.5.3 In a later stage, possible data link of eg waypoints, ETAs and RTAs may become necessary particularly if these become more complex leading to possible misunderstanding if delivered by R/T.

Identified ATM applications

3.3.5.4 This ATM application can be implemented without data link in the first stage. In the second stage, some use of data link is foreseen but mostly solving issues, which are not solved by other operational concepts such as misunderstanding in delivery by R/T. Because the requirement for data link is not well developed, no separate ATM applications have been identified for this operational concept. Instead, facilitation of free route operations is included as enabler benefits for OC1 and OC2.

3.4 Progressive delegation of responsibility to pilot

3.4.1 Description of operational context

3.4.1.1 Delegation of responsibility to pilot is expected in a series of steps supporting the following operational concepts:

- OC9: Airborne Spacing or co-operative separation assurance (COSEP)/Spacing;
- OC10: Airborne Separation or COSEP/Separation;
- OC11: Airborne Self-Separation or autonomous flight operations (AUTOPS).

Essentially, it is expected that airborne elements will take increasing responsibility for decisions and, eventually, for ensuring separation, with the ground element monitoring and intervening to ensure safety of flight only.

3.4.2 OC9: Airborne Spacing

Description

3.4.2.1 Airborne Spacing, also known as COSEP/Spacing, requires flight-crews to achieve and maintain a given spacing with designated aircraft as specified in a new ATC instruction [116]. The operational concept involves only two aircraft, or a chain of aircraft. Separation provision is still the controller's responsibility and applicable separation minima are unchanged.

Identified ATM applications

3.4.2.2 Airborne spacing includes several types of ATM applications, including level flight spacing or station keeping, lateral passing or crossing, in-descent spacing and vertical crossing. Trials and evaluation activity has identified key applications within different airspace regions. The study has therefore divided the operational concept into the following ATM applications in order to distinguish between the main airspace regions:

- **APP9a: Airborne spacing in en-route and terminal airspace.** This includes establishing in-trail spacing intervals, level spacing and in-descent spacing in core and transitional en-route and terminal airspace.
- **APP9b: Crossing and passing in en route airspace.** This includes level crossing and passing and vertical crossing in core and transitional airspace.
- **APP9c: Final approach spacing.** This is also known as improved approach spacing (CDTI enhanced flight rules) [115]. Aircraft establish and maintain separations in the approach path. Benefits arise because aircraft have the potential to maintain a separation that is closer to the allowed minimum [38].
- **APP9d: Departure spacing.** Currently departure spacing is generally controlled on a time basis: the time between departures depending on the whether the aircraft will follow or diverge from the preceding aircraft. The result of current operational practice is that aircraft tend to enter terminal airspace at separations that greatly exceed the allowed minimum. Departure spacing using ADS-B has the potential to involve the pilot in collaborative decision making for take off time based on a distance behind the preceding aircraft with the potential to achieve closer separations at the terminal area boundary [38].

3.4.2.3 The study team has assumed that usage of these ATM applications in oceanic and remote airspace will be carried out under conditions where pilots take a greater responsibility for maintaining separation. Use in oceanic and remote has therefore been covered under the airborne separation operational concept (see APP10a).

Expected dependence on data link

3.4.2.4 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- aircraft/ground point to point data link: Not expected initially. There may be a need as the operational concepts develop to use as a means of target designation.
- ground to aircraft broadcast data link: Depends on technology approach used (see paragraph 3.2.4.5).
- aircraft to aircraft broadcast data link.
- aircraft to aircraft point to point data link: Not expected initially. There may be a need as the operational concepts develop to use as a means of target designation.

Summary of benefits

<table>
<tr><td colspan="6">OC9: Airborne Spacing</td></tr>
<tr><td rowspan="4">Key</td><td>APP9a</td><td colspan="4">Airborne spacing in en-route and terminal airspace.</td></tr>
<tr><td>APP9b</td><td colspan="4">Crossing and passing in en route airspace.</td></tr>
<tr><td>APP9c</td><td colspan="4">Final approach spacing.</td></tr>
<tr><td>APP9d</td><td colspan="4">Departure spacing.</td></tr>
<tr><td colspan="2">References</td><td colspan="4">Action Plan 1: PO-ASAS [116], COOPATS [39], MFF [108], NUP: Co-operative ATS in ETMA, Station keeping [109], MA-AFAS: In- descent and level-flight spacing [110], Free Route Experimental Encounter Resolution (FREER) project [113] and EC - CO-SPACE project.</td></tr>
<tr><td colspan="2">Compliance with OCD</td><td colspan="4">Increasing use of free-routes and user-preferred trajectories.
Improved cockpit awareness of the surrounding traffic situation.
Greater use of computer support tools to reduce ATC and cockpit workload.
Limited and more extensive transfer of separation responsibility to the pilot.</td></tr>
<tr><td colspan="2" rowspan="2">Capacity</td><td>APP9a</td><td>APP9b</td><td>APP9c</td><td>APP9d</td></tr>
<tr><td>Small</td><td>Small</td><td>Medium</td><td>Small</td></tr>
<tr><td colspan="6">Increase in capacity through:
• reduction in controller workload by delegation of eg heading instructions. For APP9a and APP9b, the FREER project demonstrated significant reduction of R/T workload [113].
• better flow management (arrival sequence).
• more efficient use of airspace by achieving reduced spacings (note that under spacing – get separations closer to ground allowed separations).
APP9c makes possible in maintenance of the landing rate during conditions of poor visibility.
Capacity gains will be linked to the proportion of suitably equipped aircraft. No clear figures are currently available; however, this operational concept may deliver benefits such as making it possible to delay the moment at which you have to build a new runway (APP9c). Benefits have been documented for Stockholm [38]. Documented benefits in en-route not as clear but likely to be important in eg MFF regions, oceanic etc.</td></tr>
<tr><td colspan="2" rowspan="2">Safety</td><td>APP9a</td><td>APP9b</td><td>APP9c</td><td>APP9d</td></tr>
<tr><td>Small</td><td>Small</td><td>Small</td><td>Small</td></tr>
<tr><td colspan="6">Increase in safety due to air traffic situation awareness (see ATSAW).
In addition, pilot is more aware of the target aircraft which otherwise might conflict.</td></tr>
<tr><td colspan="2" rowspan="2">Flight efficiency</td><td>APP9a</td><td>APP9b</td><td>APP9c</td><td>APP9d</td></tr>
<tr><td>Small</td><td>Small</td><td>Small</td><td>None</td></tr>
<tr><td colspan="6">Improved flight efficiency (e.g. more stable trajectory, reduced flight time, distance and fuel consumption) (APP9a, APP9b and APP9c).</td></tr>
<tr><td colspan="2" rowspan="2">Cost effectiveness</td><td>APP9a</td><td>APP9b</td><td>APP9c</td><td>APP9d</td></tr>
<tr><td>None</td><td>None</td><td>None</td><td>None</td></tr>
<tr><td colspan="6">None identified.</td></tr>
<tr><td colspan="2" rowspan="2">Environmental impact</td><td>APP9a</td><td>APP9b</td><td>APP9c</td><td>APP9d</td></tr>
<tr><td>Small</td><td>Small</td><td>None</td><td>None</td></tr>
<tr><td colspan="6">Less fuel burnt due to better flight efficiency (in en-route and terminal).</td></tr>
<tr><td colspan="2" rowspan="2">Enabler and other benefits</td><td>APP9a</td><td>APP9b</td><td>APP9c</td><td>APP9d</td></tr>
<tr><td>Small</td><td>Small</td><td>Small</td><td>Small</td></tr>
<tr><td colspan="6">Better flow management.
Enabler to general airborne spacing/separation ATM application.</td></tr>
</table>

3.4.3 OC10: Airborne Separation

Description

3.4.3.1 Airborne Separation, also known as COSEP/Separation, involves the controller delegating separation responsibility and transferring the corresponding separation tasks to the flight crew who ensure that applicable separation minima are met. The separation responsibility delegated is limited to the designed aircraft, specified by a new clearance and is limited in space and in time. [116]

Identified ATM applications

3.4.3.2 This operational concept is a progression of the airborne spacing operational concept leading to reductions in controller workload and the potential to reduce separations. The chosen ATM applications fall into two categories:

- development of en-route, terminal and approach applications APP9a, APP9b and APP9c. The study team has assumed that these are combined into two ATM applications, one for en-route and terminal, and the other for approach.
- introduction of ATM applications for oceanic and remote regions (see previous note in paragraph 3.4.2.3).

3.4.3.3 The ATM applications associated with this operational concept are:

- **APP10a: Airborne separation in oceanic and remote airspace.** This includes in-trail climb (ITC), in-trail descent (ITD), lateral passing manoeuvres and station keeping.
- **APP10b: Airborne separation in en-route and terminal airspace.** This includes following, crossing and climb/descent manoeuvres, sequencing applications.
- **APP10c: Final approach separation.** This includes pair approaches and is the progression of APP9c but makes possible reduced approach spacings.

Expected dependence on data link

3.4.3.4 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- aircraft/ground point to point data link: For APP10b and APP10c there may be a need as a means of target designation. Phase 2 will also consider whether ground surveillance based on eg ADS-C is required for APP10a.
- ground to aircraft broadcast data link: Depends on technology approach used (see paragraph 3.2.4.5).
- aircraft to aircraft broadcast data link.
- aircraft to aircraft point to point data link: For APP10b and APP10c there may be a need to use as a means of target designation. May also be required for APP10a to maintain communication if the airborne surveillance picture is lost.

Summary of benefits

OC10: Airborne Separation				
Key	**APP10a**	Airborne separation in oceanic and remote airspace.		
	APP10b	Airborne separation in en-route and terminal airspace.		
	APP10c	Final approach separation.		
References	PO-ASAS [116]; COOPATS [39], MFF: ASAS crossing procedure [108], NUP: In-trail procedure, in non radar oceanic airspace (In-Trail Climb /Descent) (ITC/D), station keeping in terminal, Delegated airborne separation [109], MA-AFAS: lateral and vertical crossing and passing [110] and CARE/ASAS Activity 3: ASM: time based sequencing [112].			
Compliance with OCD	Increasing use of free-routes and user-preferred trajectories. More integrated planning between ATM, aircraft operators and airports. Improved cockpit awareness of the surrounding traffic situation. Greater use of computer support tools to reduce ATC workload. Limited and more extensive transfer of separation responsibility to the pilot.			
Capacity		**APP10a**	**APP10b**	**APP10c**
		Medium	Medium	Medium
The capacity benefits are the same as airborne spacing except that additional benefits become possible as a result of reduction in controller workload arising from a reduction in controller R/T and monitoring workload, better flow management (arrival sequences) and more efficient use of airspace by achieving reduced spacings that are lower than current ground allowed separations (eg APP10a enables greater use of oceanic track system). Note that reduced separations are not a pre-requisite for achieving benefit from these ATM applications. In fact, CENA current project ECLECTIC aims at showing that the profits in safety and capacity will exist *even if the airborne minima value is **higher** than that of the ATC*. The delegation of responsibility for conflict detection and resolution to the air-crew will produce gain in capacity and safety since the controller will be able to better manage the remainder of the traffic. Capacity gains will be linked to the proportion of suitably equipped aircraft and the applicable airborne separation minima. If it is proven that these minima are lower than the applicable ATC minima, gains may be increased. No benefit figures are available yet. APP10c support landing rate in poor visibility and provides potential for reduced separation in approach path and hence higher landing rate.				
Safety		**APP10a**	**APP10b**	**APP10c**
		Small	Small	Small
Safety is not the primary objective but these applications will not gain acceptance unless they are demonstrated to be as safe as the present system. Provides greater awareness of other aircraft. Possible safety improvement may result from separation being based on better position information, plus eliminating the possibility of garbled or missed communications.				
Flight efficiency		**APP10a**	**APP10b**	**APP10c**
		Medium	Medium	Small
Increase in flight efficiency resulting from the possibility for pilot to select the appropriate fuel efficient manoeuvre. APP10c: enhanced landing rates may lead to reduced holding times				
Cost effectiveness		**APP10a**	**APP10b**	**APP10c**
		None	Small	None
In the en-route regions there is the potential for a reduction in the need for ground support (ie larger sectors, fewer controllers).				
Environmental impact		**APP10a**	**APP10b**	**APP10c**
		Small	Small	Small
Fuel saving by increased use of fuel efficient routes and reduced holding times				
Enabler and other benefits		**APP10a**	**APP10b**	**APP10c**
		Small	Small	Small
Provides a step towards airborne self-separation.				

3.4.4 OC11: Airborne Self-Separation

Description

3.4.4.1 In airborne self-Separation, also known as AUTOPS, flight crews ensure separation of their aircraft from all surrounding traffic, in accordance with applicable airborne separation standards. Pilots are free to fly their user preferred trajectories.

Identified ATM applications

3.4.4.2 Different types of applications are defined in [116] including autonomous operations in free flight airspace (FFAS) and cluster control in which pilots ensure self - separation in ATC managed airspace.

3.4.4.3 The ATM applications associated with this operational concept are therefore:

- **APP11a: Cluster control in ATC managed airspace.** This will apply in core and transition airspace. In Cluster control the pilot is provided with surrounding traffic information (state + trajectory intent)
- **APP11b: Autonomous operations in FFAS.** This is expected to apply initially in remote or transitional en-route airspace and then later to high density airspace.

Expected dependence on data link

3.4.4.4 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- aircraft/ground point to point data link: There may be a need to use as a means of target designation.
- ground to aircraft broadcast data link: Depends on technology approach used (see paragraph 3.2.4.5).
- aircraft to aircraft broadcast data link.
- aircraft to aircraft point to point data link: There may be a need to use as a means of target designation and for trajectory negotiations.

Summary of benefits

OC11: Airborne Self-Separation			
Key	**APP11a**	Cluster control in ATC managed airspace	
	APP11b	Autonomous operations in FFAS	
References	PO-ASAS [116]; COOPATS [39], MFF: Airborne self separation assurance [108], MA-AFAS: Autonomous operations [110], NUP: cluster control [109], CARE/ASAS Activity 3: ASM study: Airborne Aircraft [112], EEC – FAST project and NLR : free flight study.		
Compliance with OCD	More dynamic and flexible use of airspace. Increasing use of free-routes and user-preferred trajectories. More integrated planning between ATM, aircraft operators and airports. Improved cockpit awareness of the surrounding traffic situation. Greater use of computer support tools to reduce ATC workload. Limited and more extensive transfer of separation responsibility to the pilot.		
Capacity		**APP11a**	**APP11b**
		Large	Medium
Increase in capacity through significantly more efficient aircraft operations with a complementary reduction in overall ATC effort. Increase in capacity through a reduction of airborne separation minima (if proven feasible) in airspace characterised by poor or non-existent radar coverage (e.g. remote area). Note that reduced separations are not a pre-requisite for achieving benefit from these ATM applications. See for example comments on CENA current project ECLECTIC in OC11. Reduction in controller workload through reduction in monitoring workload (see also Section 5.4.9) APP11b: Benefits apply mostly when used within core airspace – benefits in remote airspace not as great since there are currently fewer capacity constraints.			
Safety		**APP11a**	**APP11b**
		Medium	Medium
Increase in safety: these applications enable the flight crews of all aircraft involved in a conflict to have capability and authority to resolve it, thereby enabling an increase in redundancy.			
Flight efficiency		**APP11a**	**APP11b**
		Large	Large
Increase in flight efficiency; flight crews have the possibility to fly their user preferred trajectory (optimising route, e.g. direct routing, at optimum flight level).			
Cost effectiveness		**APP11a**	**APP11b**
		Medium	Medium
There is the potential for a reduction in route charges for operators. For example, in en-route regions there is the potential for a reduction in need for ground support (ie larger sectors, fewer controllers) but note that the cluster control ATM application may need a separate "cluster controller".			
Environmental impact		**APP11a**	**APP11b**
		Medium	Medium
Reduction in fuel consumption through more efficient flight profiles.			
Enabler and other benefits		**APP11a**	**APP11b**
		Small	Small
Increased user flexibility (no more ATC constraints).			

3.5 Enhanced airport surface services

3.5.1 Description of operational context

3.5.1.1 Currently, operational procedures on the surface of an airport depend on pilots, air traffic controllers, and vehicle drivers using visual observation of the location of the aircraft and vehicles in order to estimate their respective relative positions and risk of collision. Pilots and vehicle drivers rely on visual aids (lighting, signage, and markings) to guide them along their assigned routes and to identify intersections and holding points issued by the controller. During periods of low visibility, controllers must rely on the pilot's R/T reports and surface movement radar to monitor separation and to identify conflicts. In these conditions, pilots, and vehicle drivers find that their ability to operate in the "see and be seen" mode is severely impaired [119].

3.5.1.2 Enhanced Airport Surface Services are expected to provide:

- a traffic picture supporting low visibility operations and runway incursion avoidance. It is noted that the traffic picture could be provided either as an aid to the controller, or to the pilot, or to both.
- AOCs, ramp managers and surface operators can also benefit from this information.
- trajectory management including planning and delivery of clearances.

3.5.1.3 The identified operational concepts are divided into cockpit and ground domains:

- OC12: ATSAW on ground (Improved Taxiway / Runway Occupancy awareness)
- OC13: ATC surveillance and advanced surface movement guidance and control systems (A-SMGCS)

3.5.1.4 Note that communication services such as gate information, clearance delivery, ATIS and PDC are included as part of Link 2000+ services under OC2.

3.5.2 OC12: ATSAW on ground

Description

3.5.2.1 ATSAW on ground (Improved Taxiway / Runway Occupancy awareness) makes possible airborne awareness of proximate surface traffic (both aircraft and other surface vehicles) using display of the airport map on a CDTI.

Identified ATM applications

3.5.2.2 Initially ATSAW will supplement the flight crew's out of the window visual assessment of surface target position, direction, and speed on the airport surface. This is expected to develop to support:

- detection and alert for ground conflicts;
- support for surface movements in low visibility.

3.5.2.3 The ATM applications that support the stages of development of this operational concept are therefore:

- **APP12a: Surface enhanced visual acquisition.** This is also known as airport surface situational awareness (Visual Flying Rules (VFR) -day and VFR-night) and is expected to provide smoother taxiing in good weather via providing better awareness to the pilots, eliminating some of the constraints imposed by the limited visibility from the cockpit.
- **APP12b: Runway and final approach occupancy awareness.** Provides enhanced awareness of other aircraft and vehicles on the airport surface reducing the risk of runway incursions.

- **APP12c: Enhanced IMC airport surface operations.** This is similar to surface enhanced visual acquisition (APP12a) but enhances operations in reduced visibility supporting, in particular, landing and take-off and possibly taxi operations.

Expected dependence on data link

3.5.2.4 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- ground to aircraft broadcast data link: depends on the technology approach used (see paragraph 3.2.4.5):[7]
- aircraft to aircraft broadcast data link.
- Other technologies such as multilateration are also candidates.

Summary of benefits

OC12: ATSAW on ground			
Key	**APP12a**	Surface enhanced visual acquisition.	
	APP12b	Runway and final approach occupancy awareness.	
	APP12c	Enhanced IMC airport surface operations.	
References	ODIAC [97], NUP [98] and Eurocontrol ADS web site [107], European Commission funded projects [119 to 128], NASA projects [129 to 130].		
Compliance with OCD	Improved cockpit awareness of the surrounding traffic situation. Greater use of computer support tools to reduce ATC and cockpit workload.		
Capacity	**APP12a**	**APP12b**	**APP12c**
	Small	None	Medium
Improved efficiency (see below) may lead to improved capacity eg safe and efficient taxi clearances [115]. APP12c: maintain operations in reduced visibility and allow aircraft to maintain closer separations.			
Safety	**APP12a**	**APP12b**	**APP12c**
	Small	Medium	Small
Avoidance of runway incursions and collisions [115] in general is seen as very important and leading to increased safety.			
Flight efficiency	**APP12a**	**APP12b**	**APP12c**
	Small	None	Small
Airport efficiency can be improved by giving the stakeholders a common picture of the situation and expected situation. Including apron control, de icing, fuelling, catering etc. (also: take into account the CDM aspects of data linking). Potential for reduced ground holding time (but pilots may move slower if they an see another aircraft).			
Cost effectiveness	**APP12a**	**APP12b**	**APP12c**
	None	None	None
Potential to provide alternative surveillance infrastructure at small airports.			
Environmental impact	**APP12a**	**APP12b**	**APP12c**
	Small	None	Small
Reduced fuel burn from reduced holding times.			
Enabler and other benefits	**APP12a**	**APP12b**	**APP12c**
	Small	Small	Small
Enabler for further development of applications on the airport surface.			

[7] In this concept, references to aircraft applies to ground vehicles as well.

3.5.3 OC13: ATC surveillance and A-SMGCS

Description

3.5.3.1 ATC surveillance and A-SMGCS provides alternative surveillance means for ground control via ADS-B and also routing services as follows:

- In manual mode a route will be transmitted by the controller to the aircrew;
- In automatic mode: automatic clearance delivery feeding pilots (eg routes directly sent to aircrew);
- Real time change of the route or destination.

Identified ATM applications

3.5.3.2 The ATM applications associated with this operational concept are:

- **APP13a: Fusion of current terminal and/or surface radar with other surveillance means.** This provides enhanced surveillance accuracy for Center – TRACON Automation System (CTAS) and other terminal automation tools.
- **APP13b: ATC surveillance using aircraft information at airports.** This enables application of pseudo radar separation standards at airports without radar coverage
- **APP13c: Routing.** This provides routing information such as taxi clearances to aircraft on the airport surface.

Note that the benefits of APP13a and AP13b could also be delivered by multi-lateration or ADS-B and this possibility will be assessed in Phase 2.

Expected dependence on data link

3.5.3.3 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- aircraft/ground point to point data link for APP13c.
- ground to aircraft broadcast data link: APP13a and APP13b may need a Ground Based Augmentation System (GBAS) if an ADS-B solution is used.
- aircraft to ground broadcast data link for APP13a and APP13b. Note that this could be an ADS-B solution or multilateration.

Summary of benefits

OC13: ATC surveillance and A-SMGCS			
Key	**APP13a**	Fusion of current terminal and/or surface radar with other surveillance means.	
	APP13b	ATC surveillance using ADS-B at airports.	
	APP13c	Routing.	
References	ODIAC [97], NUP [98] and Eurocontrol ADS web site [107], European Commission funded projects [119 to 128], NASA projects [129 to 130].		
Compliance with OCD	More dynamic and flexible use of airspace. Improved cockpit awareness of the surrounding traffic situation. Greater use of computer support tools to reduce ATC and cockpit workload. Limited and more extensive transfer of separation responsibility to the pilot.		

	APP13a	**APP13b**	**APP13c**
Capacity	Small	Small	Medium
More optimum clearances through provision of surveillance picture. Reduces workload for controllers. Automated routing of aircraft supplying the pilots with clear and reliable information to follow the assigned route provides for more optimal ground operations. Thus, an optimised and efficient guidance of aircraft in all weather conditions along with a more expeditious ground flow of aircraft during low visibility conditions by use of specifically assigned routes and indication of any restricted areas will increase capacity, safety and efficiency. Some stakeholders believe that control ought to shift to pilot (ie like a road control system).			
Safety	Medium	Small	Medium
See above, also same as for ATSAW. Enhanced surface picture reduces eg runway incursions. Automated clearances reduce probability of misunderstanding.			
Flight efficiency	Small	Small	Medium
See above, also same as for ATSAW. Reduced ground holding time.			
Cost effectiveness	None	Small	None
Use of ADS-B offers potential to realise surveillance benefits with lower cost infrastructure (APP13b).			
Environmental impact	Small	Small	Small
Benefits resulting from reduced holding times.			
Enabler and other benefits	None	None	Small
Supports collaborative decision-making (APP13c).			

3.6 Enhanced services to remote and oceanic areas

3.6.1 Description of operational context

3.6.1.1 At present, air traffic control in oceanic/remote airspace is procedural. There is no radar surveillance and communications are limited by the capacity and performance of the high frequency (HF)[8] system currently in use. Enhanced services to remote and oceanic areas are expected to include:

- Basic surveillance infrastructure via ADS-B in remote regions;
- ATS in remote/oceanic regions via Future Air Navigation Systems (FANS).

3.6.1.2 The identified operational concepts are:

- OC14: ATS in oceanic/remote areas

3.6.2 OC14: ATS in oceanic/remote areas

Description

3.6.2.1 Provides improved surveillance and communications in oceanic/remote areas.

Identified ATM applications

3.6.2.2 The ATM applications associated with this operational concept are:

- **APP14a: Basic surveillance infrastructure via ADS-B in remote regions.** ADS-B offers the opportunity to provide a basic surveillance picture to ground controllers without the need to provide radar infrastructure.
- **APP14b: ATS in oceanic/remote areas.** This includes controller/pilot data link communications (CPDLC) services and surveillance via ADS-contract (ADS-C). ADS-C offers the opportunity to obtain greater situational awareness in oceanic airspace. ADS-C is able to provide regular position reports, position reports on demand from the controllers and position reports following an event (for example, an aircraft crossing a waypoint). CPDLC provides, for example, clearance delivery. The combination of CPDLC and ADS-C is expected to enable more efficient climb/descent and passing manoeuvres and more efficient lateral passing manoeuvres. In the analysis carried out in this document, it is assumed that the initial implementation of this ATM application will be supported by the FANS1/A equipage. It is also possible to provide this ATM application via ATN and this possibility will be investigated in more detail in Phase 2 of the study.

Expected dependence on data link

3.6.2.3 It is expected that the following types of data link will be required to support this operational concept in addition to current infrastructure:

- aircraft/ground point to point data link for APP14b. Supporting ADS-C and CPDLC services.

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[8] FANS 1/A ADS-C and some level of CPDLC are in use today in the NAT region so communications are no longer limited to HF

- aircraft to aircraft or ground broadcast data link for APP14a. Possibly also needed for APP14b noting that this ATM application may be linked to separation ATM applications in oceanic region for which an ADS-B system is required.

Summary of benefits

OC14: ATS in oceanic/remote areas		
Key	**APP14a**	Basic surveillance infrastructure via ADS-B in remote regions.
	APP14b	ATS in oceanic/remote areas.
References		IATA FANS Starter Kit.
Compliance with OCD		More integrated planning between ATM, aircraft operators and airports. Increasing use of free routes and user-preferred trajectories. Greater use of computer support tools to reduce ATC and cockpit workload.

Capacity	**APP14a**	**APP14b**
	Small	Small

Reduction in aircrew workload.

There is potential to achieve increased airspace capacity through the improved ability to establish and maintain separations.

Enables separation minima much lower than in a purely procedural environment. Considerable reduction in R/T workload

Expanded surveillance coverage in oceanic, en-route and remote non-radar airspace.

Verification of aircraft position when applying non-radar separation procedures in oceanic, en-route and remote non-radar airspace.

Note that it is not clear whether the limitations of the FANS-1/A communications protocol would result in a lower level of benefits being achieved than an implementation based on the ATN. This will be investigated further in Phase 2 of the study.

Safety	**APP14a**	**APP14b**
	Medium	Small

Enhanced situational awareness for the controller

Reduction in misinterpretation of voice data.

APP14a: Significant increase in safety by providing pseudo radar services in remote regions.

Flight efficiency	**APP14a**	**APP14b**
	None	Medium

More optimal routings.

Cost effectiveness	**APP14a**	**APP14b**
	Small	Small

APP14a: alternative to radar infrastructure.

APP14b: technology already established in several flight information regions (FIRs).

NAT is already experiencing cost reductions by moving position reporting to ACARS-based ADS-C and data linked WPRs; these have relieved the pressure for new HF channels (delay/deferring implementation costs).

Environmental impact	**APP14a**	**APP14b**
	Small	Small

Reduced fuel burn via more optimal routings.

Enabler and other benefits	**APP14a**	**APP14b**
	None	None

None identified.

4 Implementation constraints and timescales

4.1 Introduction

4.1.1 This section identifies implementation constraints and assesses the impact on the timescales for adoption of each ATM application. An important constraint is the availability of communication infrastructure which will be considered in Phase 2 of the study. Phase 1, and therefore this section, focuses on the other constraints including, for example, the timescales associated with moving ATS control infrastructure forward, getting approvals for new procedures and upgrading ground equipment.

4.1.2 A multi-criteria analysis was conducted to assess the complexity of each ATM application. The complexity is a measure of the degree of change necessary to implement an ATM application: the more complex the ATM application, the longer it will take to enter operations. The criteria selected to represent the complexity of each ATM application are discussed below.

4.1.3 **Equipage:** The ideal situation for introduction of an ATM application is when benefits depend simply on whether an aircraft is equipped and the benefits are sufficient to justify the equipage regardless of whether any other aircraft are equipped. The reality is that many ATM applications require adjacent pairs or groups of aircraft to be equipped and also for the overall aircraft population to achieve a minimum level of equipage before significant benefits can be obtained. This in turn leads to delay in implementation of the ATM application. Two criteria were therefore defined to characterise equipage issues:

- Traffic equipage characteristics: whether singe, paired or grouped equipage is required
- Percentage equipage: the minimum required equipage to realise the benefits.

4.1.4 **Impact on the current ATM process:** The degree of change introduced by an ATM application may be assessed in terms of the criticality of the services required to implement it and the impact on the current air traffic management process and procedures. These impact directly on, for example, the time taken to develop and implement infrastructure and to obtain certification and approvals. The following criteria were used to asses the ATM applications:

- safety criticality: the extent to which the ATM application requires safety critical equipment.
- conceptual considerations: whether the current air traffic control process is changed by the ATM application.
- operational procedures considerations: whether there is a need for new procedures to be designed.
- impact on airspace/airport design, management and approval: whether there is a need for airspace re-organisation, new approvals processes etc.

4.1.5 **Impact on current infrastructure:** New ATM applications will require modification to the ground and airborne infrastructure. Two criteria were used:

- Impact on ground infrastructure: consideration of the impact on controller working positions (CWP), flight data processing (FDP) and radar data processing (RDP) systems, central flow management unit (CFMU) and ground networks.

- Impact on airborne infrastructure: consideration of the impact on cockpit tools, surveillance data processing and other onboard processing.

4.1.6 The assessment levels for each criteria are defined in Table 4-1.

1	2	3	4	5
Traffic equipage characteristics				
per aircraft	aircraft pairs	groups of aircraft (in presence of non-equipped)	groups of aircraft (no non-equipped)	full equipage
Percentage equipage				
0-20%	21-40%	41-60%	61-80%	81-100%
Safety criticality				
low (eg planning function only or extension of VMC or procedural)	medium (eg sector to sector planning)	medium (tactical control but can rely on current reversion procedures)	medium (tactical control but need modification of reversion procedures)	high (tactical control little time for reversion, new reversion procedures must be defined)
Conceptual considerations				
no fundamental change to current tasks or responsibilities	small number of new tasks given to flight deck and/or controller but there is no change of current separation responsibilities	significant transfer of tasks to flight deck but there is no change of current separation responsibilities	separation responsibility delegated to flight crews in agreed and appropriate specific circumstances, apart from which controller remains responsible for separation	flight crews have responsibility for providing separations from other aircraft
Operational procedure considerations				
Small changes (eg phraseology, onboard procedures to make best use of new information)	Variation of current procedure eg automation of comm, new flow management procedures etc	Significant change affecting controller and/or pilot (eg delegation of heading)	Substantial change (eg delegation of separation)	Major change including derivation of new flight rules (eg self separation)
Impact on airspace/airport design and management				
none	minor: eg need for new certification procedures for airborne equipment, need for mandate	significant changes including need for approvals of ground equipment, widespread mandate affecting retrofit aircraft	substantial changes eg need to approve fusion of navigation and surveillance infrastructure for a safety critical application	major (requires major changes to rules of flight etc)
Impact on ground infrastructure				
no change	minor change (routine upgrade)	significant change (new subsystem)	substantial change (new subsystem and integration issues)	major change (new system)
Impact on airborne infrastructure				
no change	minor change (routine upgrade)	significant change (new subsystem)	substantial change (new subsystem and integration issues)	major change (new system)

Table 4-1: Criteria used to assess implementation constraints

4.1.7 In order to assess the time when an ATM application could enter operations, a simple implementation model was derived as illustrated in Figure 4-1.

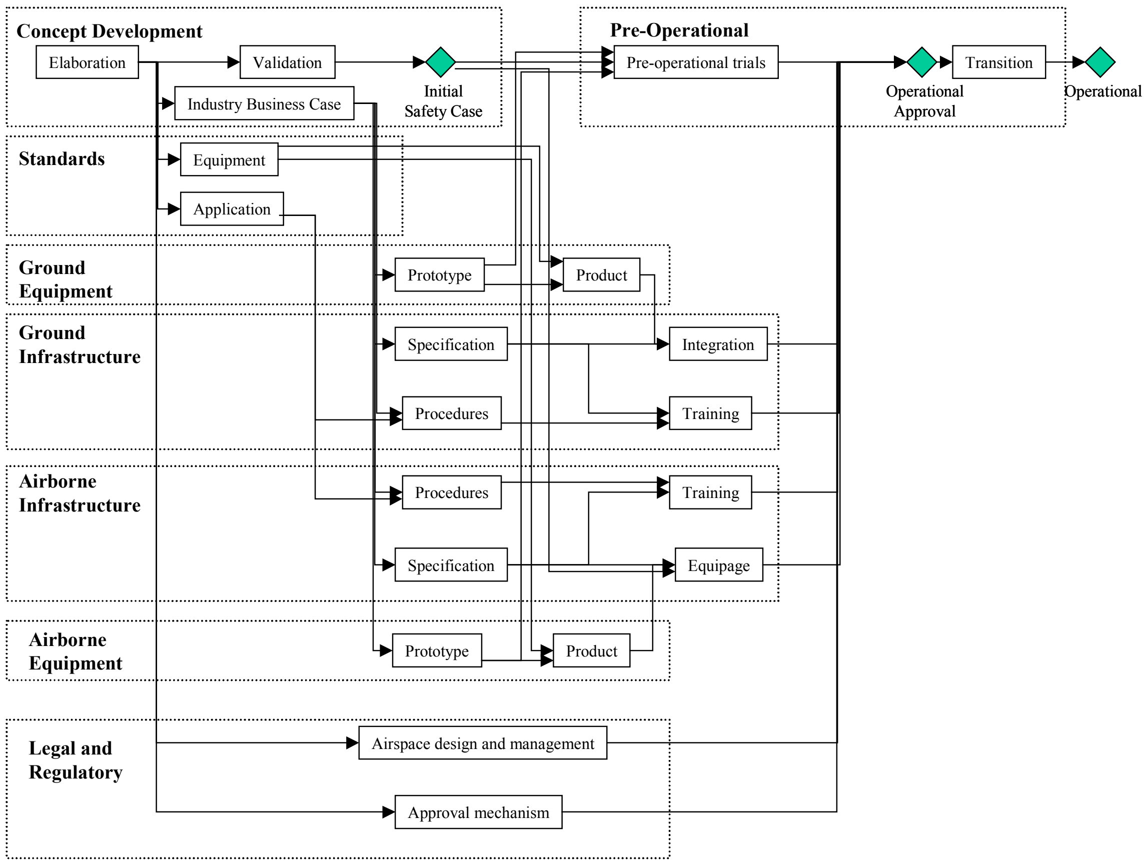

Figure 4-1: Implementation model used to assess implementation timescales

4.1.8 The implementation model illustrates the processes that have to complete before an ATM application can enter operations. The study assumes that early uses of the ATM application will start to appear from the point at which operational approval is granted and that the ATM application will become widespread by he end of the transition period.

4.1.9 Table 4-2 describes the key activities in each part of the model.

Stage	Key activities
ATM application Development	
Elaboration	Defining the ATM application leading to the production of an operational service and environment description (OSED) or equivalent
Validation	Analysis proving the validity of the ATM application including fast time simulation, real time simulation and trials. Results in finalised OSED, operational hazard analysis (OHA) and initial safety case
Industry business case	Consideration of ATM application including cost benefit analysis leading to industry commitment
Standards	
Equipment	Derivation of equipment standards to support the ATM application including ICAO technical standards, EUROCAE /RTCA Minimum Operational Performance Specification (MOPS), ETSI/EN etc
Application	Derivation of application standards to support the ATM application. Output to include ICAO application standards, EUROCAE/RTCA Minimum Aviation System Performance Specification (MASPS), etc
Ground infrastructure	
Specification	Specification of requirements for ground infrastructure
Procedures	Design of procedures for specific airspace(s)
Integration	Integration of ground equipment into current infrastructure
Training	Training for controllers and engineers
Airborne infrastructure	
Specification	Specification of requirements for airborne infrastructure
Procedures	Design of procedures for specific airspace(s)
Equipage	Installation of airborne equipment
Training	Training for pilots and engineers
Ground equipment	
Prototype	Development of prototype system (not necessarily conforming fully to ground equipment standards)
Product	Development of first generation system conformant with relevant equipment standards
Airborne equipment	
Prototype	Development of prototype system (not necessarily conforming fully to airborne equipment standards)
Product	Development of first generation system conformant with relevant equipment standards
Legal and Regulatory	
Airspace design, management and approval mechanism	Analysis of impact on airspace design and management including sectorisation, FUA, possible need for segregated airspace updated airspace rules, etc. Determination of the steps necessary to certify equipment and provide approval for the ATM application
Pre-operational	
Pre-operational trials	Trials carried out with prototype equipment to further validate the ATM application prior to operation
Transition	The period between early operational use in some areas to widespread operational use

Table 4-2: Key activities leading to implementation

Assessment of timescale

4.1.10 The assessment of timescales for each ATM application was carried out as follows:

- An assessment was made as to whether any stage in the implementation model could be considered as complete. For example, for some ATM applications the elaboration stage is complete.
- For the remaining stages judgemental analysis was used to assess how long it might take to complete the stage. The judgement was coupled deterministically to the results of the multi-criteria analysis using a weighting matrix. This ensured that the judgement was applied consistently for all operational concepts. The timescales increase in proportion to the criticality of each of the criteria that influence the particular stage.
- The output of the judgemental analysis is an estimate of the length of each stage and estimated earliest times for an ATM application to become operational. The results will be reviewed and adjusted as a result of stakeholder consultation and then further reviewed in the light of constraints imposed by the need to provide a phased implementation of supporting data link technology.

4.1.11 For each of the identified ATM applications, a time scale has been assigned based on the results of the multi-criteria analysis carried out within the study and validated by cross-reference to Eurocontrol data link strategy documents [97] and [118].

4.1.12 The timescales used in for the ATM applications have the following meanings:

- Operational approval: beginning of deployment
- Operational: the date of operational availability of the application in a significant proportion of the airspace[9].

[9] In Phase 2 of the study, the operational date was interpreted as meaning that 75% of aircraft and 75% of the ground infrastructure was equipped to support the ATM application.

4.2 Results of assessment

4.2.1 OC1: Provision of information from aircraft (including improved surveillance and downlinked aircraft data)

OC1: Provision of information from aircraft [APP1a to APP1c]

Key		
	APP1a	Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller
	APP1b	Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs
	APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace

Implementation constraints	APP1a	APP1b	APP1c
Traffic equipage characteristics: Each equipped aircraft provides data to ground system enabling benefits for that aircraft	1	1	1
Percentage equipage: [22] shows that there is a need to achieve at least 75% equipage to achieve require benefits	4	4	4
Safety criticality: APP1a/b/c: reversion procedures rely on existing surveillance services	3	3	3
Conceptual considerations: APP1b/c: Controller uses data for planning purposes	1	2	2
Operational procedure considerations: Controller carries out current task only with better information	1	1	1
Impact on airspace/airport design, management and approval: Need to consider if level C software required for eg selected altitude and whether a certification process will be needed. May need mandate to force equipage to required 75% level.	2	2	2
Impact on ground infrastructure: APP1a: Controller user interface for display of enhanced track data/RDP (incorporation of air-derived data)/ground network update. APP1b/c: Controller support tools (e.g. automatic warning, trajectory predictor), RDP (incorporation of air derived data), greater integration with FDP and CFMU (potential use of intent data), ground network update	2	3	3
Impact on airborne infrastructure: Integration with onboard data. Not straightforward for retrofit aircraft	2	2	2

Development status	Completed tasks	ALL: elaboration, equipment and application standards APP1a, APP1b: validation

Pre-operational MODE-S ground stations development; deployment of MODE-S stations from 2002 onwards; Deployment of elementary surveillance. CWP human machine interface (HMI) update is expected by 2005 (France, UK, Germany consensus). CWP tools provided by 2007 (provided that SAP exists).

New aircraft should be completed for enhanced surveillance (MODE-S) by March 2004 and retrofit 2005 (IFR) and VFR 2008 (Mode S Transition Plan). If based on Mode S: Current view is that code shortage in Mode S can be delayed until 2005. Intention is to mandate DAPs in 2005 but little belief that this will happen – hence expect delay.

Estimated timescales		APP1a	APP1b	APP1c
	Initial safety case	2000	2001	2002
	Operational approval	2004	2005	2005
	Operational	2005	2007	2007

Critical path elements

Dominated by time taken to achieve airborne equipage: Industry business case (0 to 0.5 years), equipage (2.5 to 3 years), airborne prototype (0 to 0.5 years), airborne product (0.5 to 1 year). APP1a: transition (1.5 to 2 years). APP1b, APP1c: transition (2 to 2.5 years).

Comments

OC1: Provision of information from aircraft [APP1d to APP1e]			
Key	**APP1d**	APP1d: Fusion of current radar and ADS-B surveillance in terminal and en-route airspace	
	APP1e	APP1e: ATC surveillance using ADS-B in terminal and en-route airspace	
Implementation constraints		**APP1d**	**APP1e**
Traffic equipage characteristics: Controller needs picture of large group of aircraft to achieve benefits		4	4
Percentage equipage: APP1e: Sole means hence high equipage levels required		4	5
Safety criticality: APP1d: reversion procedures rely on existing surveillance services. APP1e: use of ADS-B as sole means		3	5
Conceptual considerations: Controller uses data for planning purposes		2	2
Operational procedure considerations: Controller carries out current task only with better information		1	1
Impact on airspace/airport design, management and approval: APP1d: May need mandate to force equipage to required 75% level. APP1e: Use of ADS-B as sole means for surveillance raises issues of reliance on on-board navigation sources (ie loss of independence between navigation and surveillance). May need mandate to achieve required high equipage level		2	4
Impact on ground infrastructure: Controller user interface for display of enhanced track data/RDP (incorporation of air-derived data)/ground network update		2	2
Impact on airborne infrastructure: Integration with navigation equipment		3	3

Development status	Completed tasks	None
ADS-B first implementation by about 2005/2008 (and could be used for enhanced surveillance) (Ground Surveillance application based on ADS-B part of ADS-B Phase 1 implementation – ADS Symposium). But a wide-scale implementation not foreseen before 2008 at the earliest.		

Estimated timescales		**APP1d**	**APP1e**
	Initial safety case	2005	2006
	Operational approval	2008	2011
	Operational	2010	2015

Critical path elements

Timescales dominated by need to achieve high equipage levels

APP1d: Elaboration (0.5 to 1 year), Equipment standards (1.5 to 2 years), Equipage (2.5 to 3 years), Airborne product (1 to 1.5 years), Transition (2 to 2.5 years)

APP1e: Elaboration (1 to 1.5 year), Equipment standards (2 to 2.5 years), Equipage (3.5 to 4 years), Airborne product (1.5 to 2 years), Transition (3 to 3.5 years)

Comments

4.2.2 OC2: Enhanced communication efficiency.

OC2: Enhanced communication efficiency

Key		
	APP2a	APP2a: Pilot preferences data link
	APP2b	APP2b: Strategic controller/pilot messages
	APP2c	APP2c: Support for increased automation
	APP2d	APP2d: Trajectory negotiation

Implementation constraints	**APP2a**	**APP2b**	**APP2c**	**APP2d**
Traffic equipage characteristics: Each equipped aircraft can participate in air/ground communication enabling benefits for that aircraft	1	1	1	1
Percentage equipage: APP2b, APP2c: Assume at least 50% required to achieve benefits. APP2d: High equipage necessary to assure that up to date trajectories of most aircraft known to ground system	1	3	3	4
Safety criticality: APP2a, APP2b: Strategic messages only. APP2c, APP2d: Exchange of tactical messages. Reversion procedures rely on voice communications	1	1	3	3
Conceptual considerations: New tasks for progressive automation of current tasks and to respond to pilot requests	2	2	2	3
Operational procedure considerations: APP2b/c: Changes to procedures to respond to pilot requests for clearances . APP2d: Significant changes to flow planning tasks	1	2	2	3
Impact on airspace/airport design, management and approval: APP2b/c/d possible need for segregated airspace for equipped aircraft	1	2	2	2
Impact on ground infrastructure: APP2a/b/c: impact on controller interface and tools. Update of the ground systems to support the processing of the information eg new terminal to provide uplink information. Capable ground network required (ATN?). APP2d: New system supporting integrated planning and trajectory negotiation. Impacts on FDP and CFMU as well as control suite. Capable ground network required (high volume ATN?)	3	3	3	4
Impact on airborne infrastructure: APP2a/b/c: impact on cockpit suites and onboard networks. APP2d: Likely to need new cockpit equipment (issue for retrofit aircraft)	3	3	3	4

Development status	Completed tasks	APP2b: Elaboration, validation, industry business case, equipment and application standards, airborne infrastructure specification, ground prototype equipment, airborne prototype equipment

APP2a: Implementation programme of LINK2000+ services: on-going. Already being used in some places and some of the PETAL/Link2000+ applications in can be delivered with ACARS – but will not deliver all of the benefits. Significant impact on ATC applications, hence may delay implementation to 2005 at earliest (Maastricht will have the capability in 2003).

APP2b: Certification issues: Already some aircraft certified with system. Communications Management Unit (CMU) solution has been certified by Federal Aviation Authority (FAA). Need approvals for clearance delivery. Current certification is for baseline 1 (non time critical)

Estimated timescales		**APP2a**	**APP2b**	**APP2c**	**APP2d**
	Initial safety case	2004	2000	2005	2006
	Operational approval	2006	2002	2008	2009
	Operational	2007	2004	2010	2012

Critical path elements

APP2a: Dominated by development of ground infrastructure: Elaboration (0.5 to 1 year), industry business case (0 to 0.5 year), ground integration (0.5 to 1 year), ground equipment prototype (0.5 to 1 year), ground equipment product (1 to 1.5 years), transition (1 to 1.5 years).

APP2b/c/d timescales dominated by need to achieve high equipage: APP2b: Equipage (1 to 1.5 years), airborne product (1 to 1.5 years), transition (1.5 to 2 years). APP2c: Elaboration (0.5 to 1 year), equipment standards (1.5 to 2 years), Equipage (2 to 2.5 years), airborne product (1 to 1.5 years), transition (2 to 2.5 years). APP2d: Elaboration (1 to 1.5 year), equipment standards (1.5 to 2 years), Equipage (2.5 to 3 years), airborne product (1 to 1.5 years), transition (2.5 to 3 years)

Comments

4.2.3 OC3: Air traffic situation awareness (ATSAW).

OC3: Air traffic situation awareness (ATSAW)					
Key	**APP3a**	APP3a: Enhanced visual acquisition (EVA) in remote and oceanic airspace			
	APP3b	APP3b: Enhanced visual acquisition (EVA) in terminal airspace			
	APP3c	APP3c: Enhanced visual approaches			
	APP3d	APP3d: Traffic situational awareness in core and transitional en-route airspace			

Implementation constraints	**APP3a**	**APP3b**	**APP3c**	**APP3d**
Traffic equipage characteristics: APP3b/c: each equipped aircraft gets benefits because TIS-B is assumed APP3a and APP3d: Requires groups of aircraft to be equipped because ADS-B only is assumed	4	1	1	4
Percentage equipage: APP3b/c note that this is assumed to be small but there may be a need to achieve a higher equipage rate to justify costs of TIS-B system	4	1	1	4
Safety criticality: APP3a/b/d: extension of VMC. APP3c: operations in low visibility push "VMC envelope" further [115]	1	1	2	1
Conceptual considerations: No change	1	1	1	1
Operational procedure considerations: No change	1	1	1	1
Impact on airspace/airport design, management and approval: No change	1	1	1	1
Impact on ground infrastructure: APP3a: Assumes high equipage ADS-B solution (TIS-B not practical). APP3b/c: Provision of TIS-B data from existing surveillance system provided over "local area" airport region. ISSUE: Assumes TIS-B is provided – alternative is high equipage ADS-B solution. APP3d: TIS-B assumed over wide area	1	3	3	4
Impact on airborne infrastructure: Display of traffic information, Airborne surveillance capability, Airborne surveillance processing system (fusion of TIS-B and ADS-B data), integration with navigation equipment.	3	3	3	3

Development status	Completed tasks	All ATM applications: elaboration

Concept and Procedures under development;

Validation foreseen using fast-time, real-time simulations, flight trials, safety case (MFF, MA-AFAS and NUP)

ADS-B: first implementation not foreseen before 2006/2008 (maybe first a/c equipped around 2005)

Estimated timescales		**APP3a**	**APP3b**	**APP3c**	**APP3d**
	Initial safety case	2003	2003	2003	2003
	Operational approval	2007	2005	2005	2007
	Operational	2008	2006	2006	2008

Critical path elements

APP3a, APP3d: Dominated by need to achieve high equipage: Equipment standards (0.5 to 1 year), Equipage (2.5 to 3 years), Airborne product (0.5 to 1 year), transition 1 to 1.5 years

APP3b, APP3c: Dominated by timescales required to implement TIS-B: Industry business case (0 to 0.5 years), equipment standards (1 to 1.5 years), ground integration (0.5 to 1 year), ground equipment prototype (0.5 to 1 years), ground equipment product (1 to 1.5 years), transition (1 to 1.5 years)

Comments

APP3a: Note that earlier implementation of EVA in remote regions is possible where the local fleet can be equipped quickly. Such early implementations include North Sea helicopter operations and operations based on the current CAPSTONE trials in Alaska.

4.2.4 OC4: Provision of information to aircraft

OC4: Provision of information to aircraft		
Key	**APP4a**	APP4a: Provision of D-OTIS (ATIS, METAR) and D-RVR
	APP4b	APP4b: Provision of full range of uplink information services

Implementation constraints	APP4a	APP4b
Traffic equipage characteristics: Benefits to aircraft enabled by single equipage	1	1
Percentage equipage: Assumed low but may need higher equipage to justify infrastructure investment	1	1
Safety criticality: Low – part of planning process	1	1
Conceptual considerations: New tasks for progressive automation of current tasks and to respond to pilot requests	2	2
Operational procedure considerations: No change	1	1
Impact on airspace/airport design, management and approval: No change	1	1
Impact on ground infrastructure: Needs a considerable change in current ground FDP systems to provide the ability to handle changes to aircraft flight plans in real time, which might effect the timeframe.	3	3
Impact on airborne infrastructure: Update of the interface to display the message content. Adaptation of onboard network	3	3

Development status	Completed tasks	APP4a: Elaboration, validation, industry business case, equipment and application standards, airborne infrastructure specification, ground prototype equipment, airborne prototype equipment

D-ATIS: under development as part of Link2000+ services and already been implemented over ACARS in 26 locations in Europe.

Estimated timescales		APP4a	APP4b
	Initial safety case	2000	2007
	Operational approval	2002	2009
	Operational	2004	2010

Critical path elements

APP4a: Timescales dominated by need to achieve high equipage

APP4b: Timescales dominated by development of ground infrastructure:

APP4b: Elaboration 0.5 to 1 year, Industry business case (0 to 0.5 years), Ground integration (0.5 to 1 year), Ground equipment prototype (0.5 to 1 year), Ground equipment product (1 to 1.5 years), transition (1 to 1.5 years)

Comments

CENA comment: For OC4/D-OTIS : this service is already available in some areas : ATID is already input as text and broadcast both by vocal link (through automatic reading) and data-link (through ACARS/FANS 1 today, VDL2/ATN later).

4.2.5 OC7: Dynamic route availability

OC7: Dynamic route availability		
Key	**APP7a**	Provision of information on route availability (DYNAV)

Implementation constraints	**APP7a**
Traffic equipage characteristics: Benefits to aircraft enabled by single equipage	1
Percentage equipage: Assumed low but may need higher equipage to justify infrastructure investment	1
Safety criticality: Low – part of planning process	1
Conceptual considerations: New tasks for progressive automation of current tasks and to respond to pilot requests	2
Operational procedure considerations: Need to obtain and make available up to date information on airspace/route availability – implies coordination with eg military control	3
Impact on airspace/airport design, management and approval: Need to provide airspace flexibility	2
Impact on ground infrastructure: impact on controller interface and tools. Update of the ground systems to support the processing of the information eg new terminal to provide uplink information. Capable ground network required (ie Aeronautical Telecommunications Network (ATN))	3
Impact on airborne infrastructure: Update of the interface to display the message content. Adaptation of onboard network	3

Development status	Completed tasks	None

COOPATS [39] states that it enables later movement of responsibilities by introducing route flexibility which eventually will lead to the introduction of designated "Free-flight " airspace.

Within ODIAC [97] a DYNAV service has been introduced where the objective is to automate the provision of route changes when alternative routing can be offered by the ATS unit

Airborne side: Display of similar messages already exists (e.g. Aircraft Communication and Reporting System (ACARS))

Ground side: ground system to be updated

Estimated timescales		**APP7a**
	Initial safety case	2005
	Operational approval	2007
	Operational	2009

Critical path elements

Timescales dominated by time taken to evolve ground procedures:

Elaboration (0.5 to 1 year), Application standards (1 to 1.5 years), Ground procedures (1 to 1.5 years), Ground training (1 to 1.5 years), transition (1.5 to 2 years)

Comments

4.2.6 OC9: Airborne Spacing

OC9: Airborne Spacing		
Key	**APP9a**	Airborne spacing in en-route and terminal airspace
	APP9b	Crossing and passing in en route airspace
	APP9c	Final approach spacing
	APP9d	Departure spacing

Implementation constraints	APP9a	APP9b	APP9c	APP9d
Traffic equipage characteristics: Concept requires pairwise equipage	2	2	2	2
Percentage equipage: APP9c: Arlanda data indicates 40% to achieve benefits [38]	2	2	2	2
Safety criticality: Reversion procedures rely on existing surveillance infrastructure and control procedures	3	3	3	3
Conceptual considerations: APP9a/b and c: transfer of heading and speed to pilot. APP9c same but also separation maintained down to but not below separation standards (more critical environment?)	2	2	3	2
Operational procedure considerations: Transfer of separation tasks	3	3	3	3
Impact on airspace/airport design, management and approval: Potential to greatly delay the process as a new certification approach may have to be defined and adapted to these applications. As some applications have ground interface, a ground "certification" process may have to be envisaged, similar to the airborne certification process, to ensure that the ground systems meet the published performances and integrity performances.	2	2	2	2
Impact on ground infrastructure: Provision of TIS-B data from existing surveillance system provided over "wide area" en-route region. Assumes TIS-B is provided – alternative is high equipage ADS-B solution. APP9c/d: Potentially easier to provide TIS-B in approach and departure environment	4	4	3	3
Impact on airborne infrastructure: airborne surveillance function (connection with FMC for ADS data), CDTI, traffic information processing function and airborne spacing functions (to provide the spacing information to the pilot and specific alerts), airborne surveillance processing system (fusion of TIS-B and ADS-B data), integration with navigation equipment.	4	4	4	4

Development status	Completed tasks	APP9c: elaboration, validation, equipment and application standards

Concept and procedures under development. Validation foreseen using fast-time, real-time simulations, flight trials, safety case (MFF, MA-AFAS and NUP). Airborne equipage limits introduction to 2005 at earliest in core area and more likely 2007 (only to new aircraft). The aircraft does not need a complete picture of surrounding traffic. The earliest implementation should consider applications in which both aircraft are ADS-B equipped which do not require TIS-B or data fusion

On the airborne side: spacing task automation (i.e. aircraft guidance and control systems) might raise the criticality of the application and therefore the implementation cost (e.g. need of redundancy)

Estimated timescales		APP9a	APP9b	APP9c	APP9d
	Initial safety case	2004	2004	2001	2004
	Operational approval	2006	2006	2005	2006
	Operational	2009	2009	2007	2009

Critical path elements

Timescales dominated by changes to ground procedures: APP9a, APP9b, APP9d: Elaboration (1 to 1.5 years), Application standards (1 to 1.5 years), Ground procedures (1.5 to 2 years), Ground training (1.5 to 2 years), transition (2 to 2.5 years). APP9c: Industry business case (0.5 to 1 years), Ground procedures (1.5 to 2 years), Ground training (1.5 to 2 years), transition (2 to 2.5 years)

Comments

4.2.7 OC10: Airborne Separation

OC10: Airborne Separation		
Key	**APP10a**	Airborne separation in oceanic and remote airspace
	APP10b	Airborne separation in en-route and terminal airspace
	APP10c	Final approach separation

Implementation constraints	**APP10a**	**APP10b**	**APP10c**
Traffic equipage characteristics: Concept requires pairwise equipage	2	2	2
Percentage equipage: Arlanda data indicates 40% to achieve benefits [38] for spacing – assumed the same for separation	2	2	2
Safety criticality: APP10a: assumes aircraft are cleared to carry out manoeuvres under own responsibility – but that there is time to use a voice back up if surveillance picture fails. APP10b/c: Criticality of the airborne equipment is higher than for spacing application; airborne (redundancy and integrity) requirements will be much more stringent and therefore impact the implementation costs	3	4	4
Conceptual considerations: Limited transfer of separation responsibility – not judged as critical in APP10a	2	4	4
Operational procedure considerations: Transfer of tasks	3	4	4
Impact on airspace/airport design, management and approval: Airborne Separation minima and possibly new rules of the air, have to be defined; that will add more delay in the implementation.	2	4	4
Impact on ground infrastructure: Provision of TIS-B data from existing surveillance system provided over "wide area" en-route region. Assumes TIS-B is provided – alternative is high equipage ADS-B solution. APP10c: Potentially easier to provide TIS-B in approach environment	1	4	3
Impact on airborne infrastructure: airborne surveillance function (connection with FMC for ADS data), CDTI, traffic information processing function and airborne spacing functions (to provide the spacing information to the pilot and specific alerts) Airborne surveillance processing system (fusion of TIS-B and ADS-B data), integration with navigation equipment.	4	4	4

Development status	Completed tasks	None

ATM application and Procedures under development;

Validation foreseen using fast-time, real-time simulations, flight trials, safety case (MFF, MA-AFAS and NUP)

Technology already established in several FIRs to support ITC/ITD.

In the Pacific area several FANS installations are operational and support ITC/ITD applications (see also APP14b)

Estimated timescales		**APP10a**	**APP10b**	**APP10c**
	Initial safety case	2005	2007	2007
	Operational approval	2008	2011	2011
	Operational	2010	2015	2015

Critical path elements

Timescales dominated by changes to ground procedures:

APP10a: Elaboration (1 to 1.5 years), Application standards (1 to 1.5 years), Ground procedures (1.5 to 2 years), Ground training (1.5 to 2 years), transition (2 to 2.5 years)

APP10b, APP10c: Elaboration (1.5 to 2 years), Application standards (2 to 2.5 years), Ground procedures (2 to 2.5 years), Ground training (2 to 2.5 years), transition (4 to 4.5 years)

Comments

4.2.8 OC11: Airborne Self-Separation

OC11: Airborne Self-Separation			
Key	**APP11a**	Cluster control in ATC managed airspace	
	APP11b	Autonomous operations in FFAS	

Implementation constraints	**APP11a**	**APP11b**
Traffic equipage characteristics: Need groups of aircraft equipped to carry out self-separation	4	5
Percentage equipage: APP11a: high equipage in segregated airspace. APP11b: Sole means hence high equipage levels required	4	5
Safety criticality: Aircraft equipment is the sole means of ensuring separation from other aircraft. The criticality of equipment is very high accordingly. High redundancy and integrity requirements exist with possible high implementation costs	5	5
Conceptual considerations: Substantial change in separation responsibility	5	5
Operational procedure considerations: Wholescale transfer of responsibility to pilot	5	5
Impact on airspace/airport design, management and approval: New ATM application with high impact on both controller and pilot sides	5	5
Impact on ground infrastructure: Provision of TIS-B data from existing surveillance system provided over "wide area" en-route region – note that it may also need to provide aircraft intent. Assumes TIS-B is provided – alternative is high equipage ADS-B solution. Tailoring of existing CWP to support designation of clustered aircraft	3	3
Impact on airborne infrastructure: airborne surveillance function (connection with FMC for ADS data), CDTI, traffic information processing function and airborne spacing functions (to provide the spacing information to the pilot and specific alerts) Airborne surveillance processing system (fusion of TIS-B and ADS-B data), integration with navigation equipment.	4	4

Development status	Completed tasks	None

Cluster control is currently being developed based on Maastricht airspace

Procedures under development. Validation using fast time and real time simulations, flight trials, safety analysis

New ATM application with high impact on both controller and pilot sides;

- **Dedicated procedures** will have to be defined describing the new tasks of both controllers and pilots;
- **Transition procedures** will have to be defined;
- **Appropriate training** will have to be provided to ensure a safe and efficient application of this new operational concept.
- **Regulatory issues**: Airborne Separation minima and new rules of the air, will have to be defined. ICAO approval process to be undertaken.

Estimated timescales		**APP11a**	**APP11b**
	Initial safety case	2008	2008
	Operational approval	2013	2013
	Operational	2018	2018

Critical path elements

Timescales limited by evolution of ground procedures

All: Elaboration (2 to 2.5 years), Application standards (3 to 3.5 years) Ground procedures (3 to 3.5 years), ground training (3 - 3.5 years), transition (5 to 5.5 years)

Comments

4.2.9 OC12: ATSAW on ground

OC12: ATSAW on ground

Key		
	APP12a	Surface enhanced visual acquisition
	APP12b	Runway and final approach occupancy awareness
	APP12c	Enhanced IMC airport surface operations

Implementation constraints	APP12a	APP12b	APP12c
Traffic equipage characteristics: Single aircraft benefit because of assumed TIS-B service	1	1	1
Percentage equipage: Assumed to be low but may need to be higher to justify investment	1	1	1
Safety criticality: APP12c: reduced separation in low visibility - hence more like ASAS spacing application in terms of criticality	1	1	3
Conceptual considerations: APP12c: partial delegation to pilot of separation responsibility in low visibility conditions	1	1	3
Operational procedure considerations: APP12c: Delegation to pilot in low visibility conditions	1	1	3
Impact on airspace/airport design, management and approval: APP12c: need for approvals for operation in low visibility	1	1	2
Impact on ground infrastructure: Provision of TIS-B data from existing surveillance system provided over "local area" airport region. Assumes TIS-B is provided – alternative is high equipage ADS-B solution.	3	3	3
Impact on airborne infrastructure: Display of traffic information, Airborne surveillance capability, Airborne surveillance processing system (fusion of TIS-B and ADS-B data), integration with navigation equipment.	3	3	3

Development status	Completed tasks	None

NUP. In Phase 1 applications were defined and analysed at CDG airport. In Phase 2 a several applications of various complexity will be implemented in Toulouse, Brussels, Arlanda, Copenhagen and Helsinki in the timeframe 2001- 2005.

Estimated timescales		APP12a	APP12b	APP12c
	Initial safety case	2004	2004	2005
	Operational approval	2006	2006	2007
	Operational	2007	2007	2009

Critical path elements

Timescales dominated by need to provide a TIS-B system

APP12a/b: Elaboration (0.5 to 1 year), industry business case (0 to 0.5 years), ground infrastructure integration (0.5 to 1 year), ground equipment prototype (0.5 to 1 year), ground equipment product (1 to 1.5 years), transition (1 to 1.5 years)

APP12c: Elaboration (0.5 to 1 year), application standards (1.5 to 2 years), ground procedures (1 to 1.5 year), ground training (1 to 1.5 years), transition (1.5 to 2 years)

Comments

4.2.10 OC13: ATC surveillance and A-SMGCS

OC13: ATC surveillance and A-SMGCS				
Key	**APP13a**	Fusion of current terminal and/or surface radar with other surveillance means		
	APP13b	ATC surveillance using ADS-B at airports.		
	APP13c	Routing		
Implementation constraints		**APP13a**	**APP13b**	**APP13c**
Traffic equipage characteristics: APP13a/b: groups of aircraft needed to provide surveillance picture to controller. APP13c assumes benefits come per aircraft		4	4	1
Percentage equipage: APP13a, APP13c: assume at least moderate equipage levels to get benefit. APP13b: Sole means hence high equipage levels required		3	5	3
Safety criticality: APP13a/c: Reversion procedures rely on existing services. APP13b: system is used to establish ground separation		3	5	3
Conceptual considerations: Based on current concepts – with small modifications		2	2	2
Operational procedure considerations: Changes to tasks to provide automation		2	2	2
Impact on airspace/airport design, management and approval: APP13b: May need mandate to achieve required high equipage level.		1	3	1
Impact on ground infrastructure: Modifications to indicate new plot data source and to facilitate delivery of routing information. Update to FDP and CFMU to provide automated routings. Update to RDP to handle new target data. Update to ground networks to provide routing of new data in local airport area		3	3	3
Impact on airborne infrastructure: integration with navigation equipment, Update of cockpit tools to provide receipt and transmission of routing information, integration of routing information		3	3	3
Development status	Completed tasks	APP13a, APP13b: Elaboration		
Estimated timescales		**APP13a**	**APP13b**	**APP13c**
	Initial safety case	2004	2005	2005
	Operational approval	2007	2010	2008
	Operational	2009	2013	2010

Critical path elements

Dominated by time taken to achieve equipage

APP13c: Elaboration (0.5 to 1 year)

APP13a, APP13c: Equipment standards (1.5 to 2 years), equipage (2 to 2.5 years), airborne product (1 to 1.5 years), transition (2 to 2.5 years)

APP13b: Equipment standards (2 to 2.5 years), equipage (3.5 to 4 years), airborne product (1.5 to 2 years), transition (3 to 3.5 years)

Comments

Note that shorter timescales may be possible for APP13a if the concept is based on eg multi-lateration – to be considered further in Phase 2

Note also that APP13b is targeted by JAFTI [[115] and Eurocontrol Package 1 [116] for earlier timescales than are derived here. In [116] the intention is that basic surveillance can be provided at small airports. The analysis in this table is focussed on busy airports and the requirement for high equipage rates. It is possible that APP13b could be achieved in the timescale 2006 – 2009 at smaller airports with local fleets where high equipage levels can more easily be achieved.

4.2.11 OC14: ATS in oceanic/remote areas

OC14: ATS in oceanic/remote areas		
Key	**APP14a**	Basic surveillance infrastructure via ADS-B in remote regions
	APP14b	ATS in oceanic/remote areas

Implementation constraints	APP14a	APP14b
Traffic equipage characteristics: Ground surveillance picture requires groups of aircraft to be equipped	4	4
Percentage equipage: APP14b: Assume at least moderate equipage levels to get benefit. APP14a: Sole means hence high equipage levels required	5	3
Safety criticality: Matched to appropriate separation standards	2	2
Conceptual considerations: APP14b/c: New procedures to make it possible for control process to take advantage of surveillance picture	1	2
Operational procedure considerations:	1	1
Impact on airspace/airport design, management and approval: APP14b: existing system. APP14a/c: May need mandate to achieve high equipage	3	1
Impact on ground infrastructure: APP14a: Transfer of surveillance data from remote sites. APP14b: Simple CWP and radar upgrade to support basic ATS.	3	2
Impact on airborne infrastructure: Integration with navigation systems. APP14b based on current equipment	3	3

Development status	Completed tasks	APP14a: Elaboration, validation, equipment standards, application standards APP14b: All except equipage (based on roll out of current system)

In the Pacific area and over Asia several FANS routes are operational. CPDLC element in use over North Atlantic. Use in EUR and US continental airspace being investigated.

Note that ADS-C provides surveillance information via a point-to-point communications link. The ways that it could be developed are to make additional information available or to change the way the surveillance information is used by the controller. The current standards cater for the aircraft's current position and intent (in the form of subsequent waypoints) to be transmitted to the ground. Additional aircraft parameters could be downlinked but have not yet been considered in detail. The information could be used to provide tactical control, however this may require a much higher update rate. When considering a radar-like surveillance service for oceanic airspace, the latency of the data link may start to present a limitation on what level of tactical control can be achieved. It is therefore considered likely that future developments, beyond what could be achieved using the current ADS-C standards should be based upon ADS-B (see also APP10a). This will be assessed further in Phase 2 of the study.

Estimated timescales		APP14a	APP14b
	Initial safety case	2002	2002
	Operational approval	2008	2004
	Operational	2010	2004

Critical path elements

Timescales dominated by need to achieve equipage:

APP14a: Industry business case 0.5 to 1 year, airborne prototype equipment (0.5 to 1 year), airborne equipment (1 to 1.5 years), equipage (3 to 3.5 years), transition (1.5 to 2 years)

APP14b: equipage (2 to 2.5 years). Note that this assumes a system based on FANS1/A. If based on an ATN system, introduction might be expected in the period 2006 to 2008.

Comments

Comment from CENA: As these applications are expected to be based solely upon ADS-B on this study, the dates are rather far in the future. Today, ATS services are already given in such areas through ADS-C (that is ADS but not broadcast, using FANS 1/A). See ATC Market report Volume 11, No7 (April the 4th, 2002), pages 7-8.

5 Benefit analysis

5.1 Introduction

5.1.1.1 Section 3 provided an initial analysis of the benefits that each ATM application could deliver. The purpose of this section is to analyse the issue of benefits in greater depth and to use the results to provide a prioritisation of the ATM applications.

5.1.1.2 The approach is as follows:

- Section 5.2 presents the current situation indicating the costs that are incurred by the airline industry and explaining how these costs depend on the ATM system.
- Section 5.3 looks at the impact of not taking action to develop the ATM system. This section estimates the scale of possible benefits of introducing new ATM applications.
- Section 5.4 assesses possible options for developing the ATM system. The focus is on provision of capacity since the main disbenefit of doing nothing is to fail to provide sufficient capacity to meet demand with the result of increasing delays and losing opportunities to provide new flights. Recommendations on the priority for development of ATM applications are made.
- Section 5.5 provides a summary.

5.2 Current situation

5.2.1 General

5.2.1.1 The airline industry and Europe as a whole is incurring substantial costs to provide air transport in Europe. Many of these costs are related directly to the operation of aircraft and customer management. However, a significant part of the costs result from the ATM system. These include:

- the cost of providing an ATM service, assigned to operators via user charges;
- the costs associated with delays imposed by ATM;
- the costs associated with inefficient routing and trajectories.

5.2.1.2 A further impact is that much of the ATM system is operating near to capacity. This causes delays in the short term and suppresses demand in the longer term, preventing the growth of air traffic on some routes.

5.2.1.3 This section looks at these costs in detail with reference to the current situation. The anticipated traffic growth is presented first. Thereafter, the costs are described according to the main categories of potential benefit:

- Safety;
- Capacity;
- Flight efficiency;

- Cost effectiveness.

5.2.1.4 Note that it is assumed that environmental benefits are linked directly to flight efficiency. Hence they will not be considered further in this section.

5.2.2 Traffic levels and future growth

5.2.2.1 Table 5-1 shows the number of air traffic movements in 1998 and 1999.

January – September	Average Daily Flights	Average Daily ACC movements
1998	20,880	63,476
1999	22,213	69,488

Table 5-1: ECAC Air Traffic Movements *[Ref. 156]*

5.2.2.2 Although traffic growth levels have been impacted by the events of 11 September 2001, overall levels are expected to return to previous forecasts as illustrated in Figure 5-1.

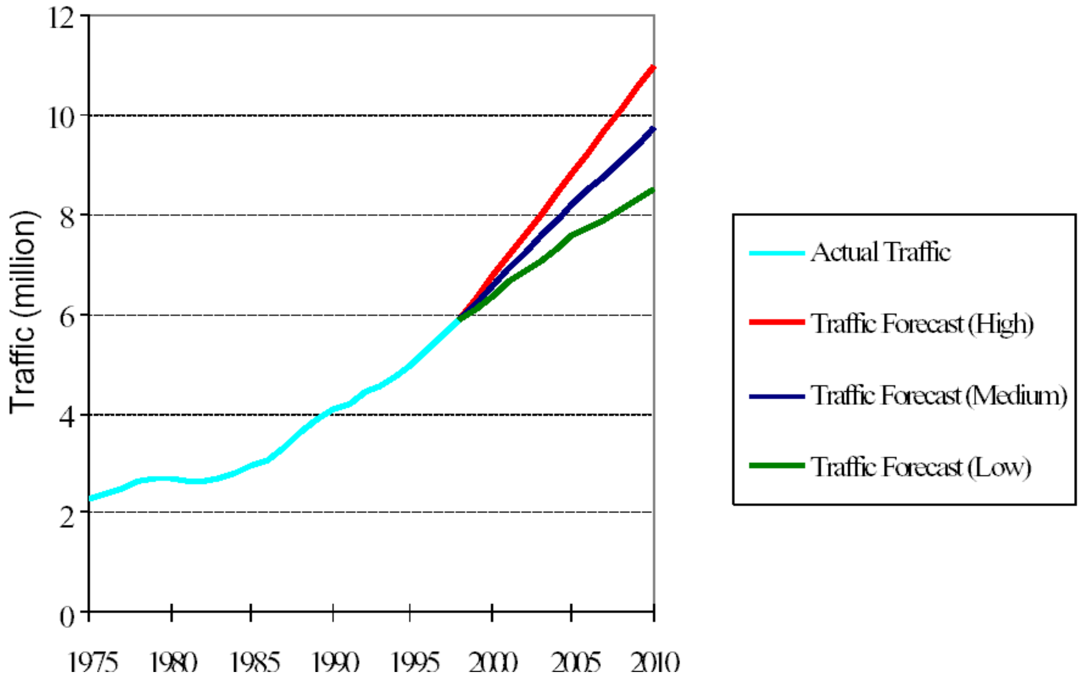

Figure 5-1: European Air Traffic growth forecast *[Ref. 106]*

5.2.2.3 From a global perspective, the airline industry supported the movement of almost 2 billion passengers in 2000 with a fleet size of almost 18,000 aircraft as illustrated in Table 5-2.

Passenger ('000)	RPKs (millions)	FTKs ('000)	Employees	No. Aircraft
1,819,969	3,274,837	137,274,159	2,382,848	17,912

Table 5-2: Total World Traffic *[Ref. 155]*

5.2.2.4 This supports an industry with a total turnover of $1.3 trillion. IATA figures indicate that the number of aircraft and traffic levels are expected to continue to grow as illustrated in Table 5-3.

Year	Number of Aircraft	Traffic (billion RPM[10])
1990	9310	1352
1995	11066	1576
2000	13501	2073
2005	16308	2686
2010	19460	3413

Table 5-3: World Airline Revenue *[Ref. 162]*

5.2.2.5 Although the forecasts vary, it is generally accepted that traffic levels will at least double by the year 2015.

5.2.2.6 In supporting this growth of traffic, the airline industry faces many challenges, not least in generating sufficient profit to sustain future growth. Overall profits have fallen year on year in the last four years as shown in Figure 5-2.

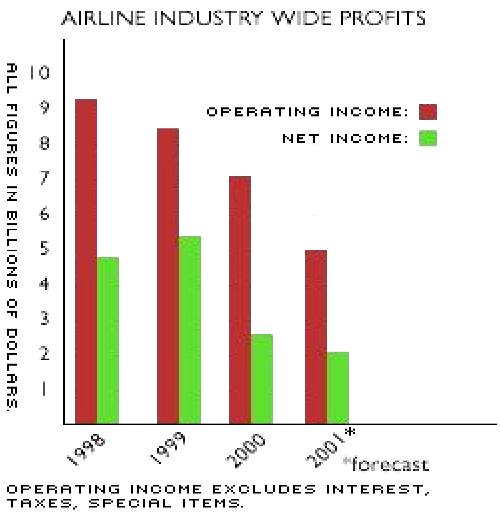

Figure 5-2: Airline industry wide profits (source IATA)

5.2.2.7 Hence, airlines have become increasingly focussed on reducing their cost base, particularly those aspects related to air traffic management. Table 5-4 illustrates 1997 figures for the cost of operating commercial aircraft. ATM related costs include:

- direct costs associated with en-route and landing charges
- indirect costs which are associated with inefficient trajectories and ground and airborne holding which primarily impact on fuel and oil costs but are also a contributory factor to maintenance, repair and depreciation costs.

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[10] Revenue Passenger Miles

All units in $ per hour	Cost per hour	Ground cost of ATFM delay	Cost per additional hour of flight time
Flight deck crew	517	517	517
Fuel and Oil	543		543
Flight equipment insurance	20	20	20
Maintenance and overhaul	683		683
Flight equipment depreciation	464	464	
Rentals	439	439	439
Landing charges	490		
En-route charges	419		
Total	3574	1440	2202
Eur/min		21.2	32.4

Table 5-4: Direct operating costs of carriers operating in Europe [Ref. 161]

5.2.2.8 Figure 5-3, taken from a different source, confirms that costs associated with flight operations are a significant part of the costs incurred by the airline industry.

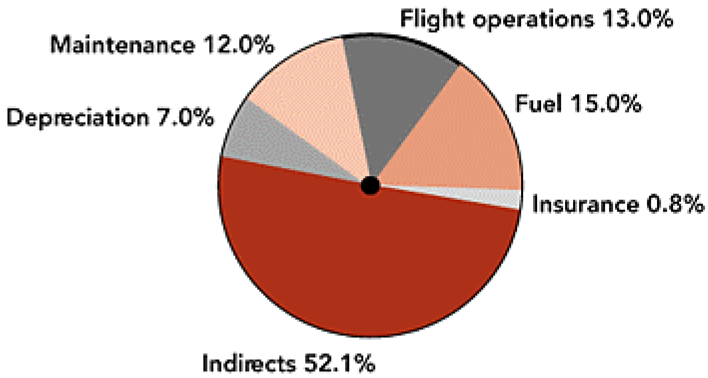


Figure 5-3: Airline Operating Cost Distribution ***[Ref. 162]***

5.2.2.9 The remainder of this section examines each contribution to ATM and assesses the impact on costs borne by the airline industry.

5.2.3 Safety

5.2.3.1 Air transport operates against a background of low levels of significant safety related incidents or accidents which, aside from the costs associated with each incident or accident, each of them tend to damage passenger confidence in the industry.

5.2.3.2 Figure 5-4 shows that the global accident rate has decreased in time and now appears relatively stable at 0.1% of aircraft in operation per year for aircraft operating out of industrialised countries.

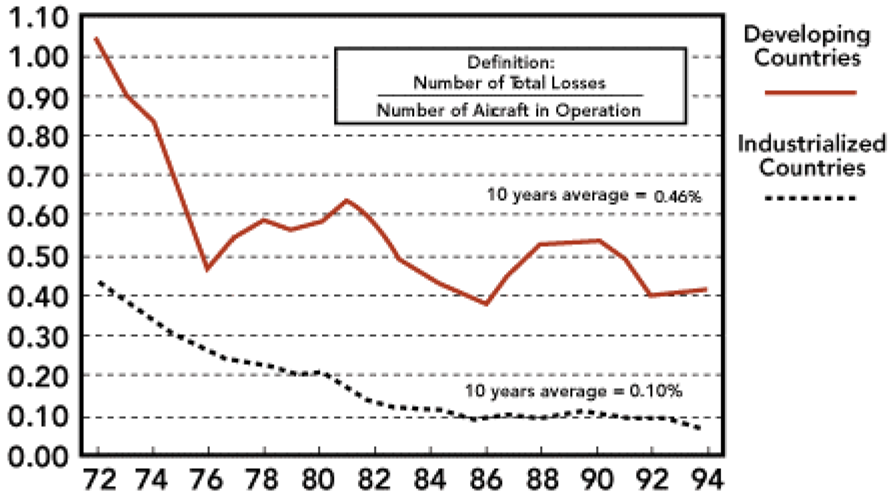


Figure 5-4: History of world accident rate (% per year) ***[Ref. 162]***

5.2.3.3 Table 5-5 shows a similar constant level of accident rate and also shows the number of passenger fatalities.

Year	No. of accidents	No. of fatalities
1990	40	604
1991	44	1076
1992	46	1490
1993	40	1002
1994	43	1390
1995	48	1100
1996	44	2100
1997	38	1232
1998	37	1093
1999	41	706
total	**421**	**11793**

Table 5-5: World-wide Jet & Turboprop Fatal accidents ***[Ref. 159]***

5.2.3.4 Over this period, out of the cumulative 421 accidents:

- 18% were due to lack of situational awareness in the air;
- 14% were due to inappropriate action taken;
- 8% were due to flight handling;
- 6% were due to “press-on-it is”;
- 3% were due to poor judgment/airmanship.

5.2.3.5 Table 5-6 shows data for the airport surface in the ECAC region.

Year	Aircraft Movements	Ground Accidents
1990	8181600	3
1991	7830600	3
1992	7969500	4
1993	7883300	4
1994	8149300	4
1995	8733800	2
1996	8985000	4
1997	9434250	4
1998	9905963	4
1999	1040126	3
total	**78113439**	**35**

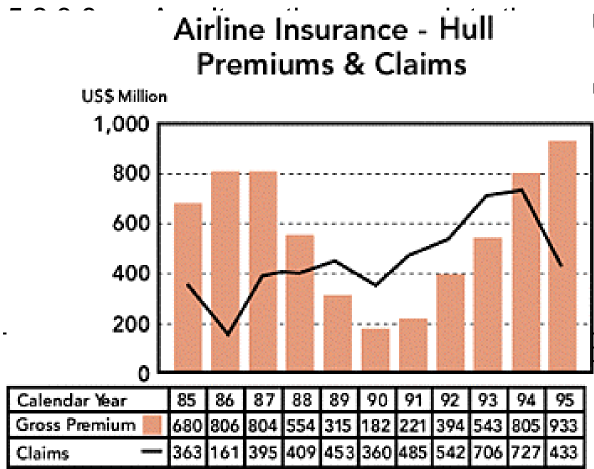
Table 5-6: ECAC ground accidents *[Ref. 160]*

5.2.3.6 Table 5-7 shows the breakdown by cause of the incidents within the ECAC region.

Types of incidents	Occurrences
Separation Minima Infringement	499
Unauthorised penetration of airspace	491
Aircraft deviation from ATM clearance	149
Runway incursion	48
Aircraft deviations from published ATM procedures	39
Inadequate separation	8
Near controlled flight into terrain	5
Runway excursion by aircraft	2
Other types of incidents	82

Table 5-7: ECAC Safety Occurrence incidents *[Ref. 106]*

5.2.3.7 The benefits expected from datalink will be measured as their capability to contribute to the SRC objective as expressed in ESARR 4: an ECAC Safety minimum of a “maximum tolerable probability of ATM directly contributing to an accident of a Commercial Air transport aircraft of 1,55*10-8 accidents per Flight Hour”. The objective has been defined to maintain to the current level of 0,623 accidents per year the number of annual ATM related accidents, in spite of the expected traffic growth.



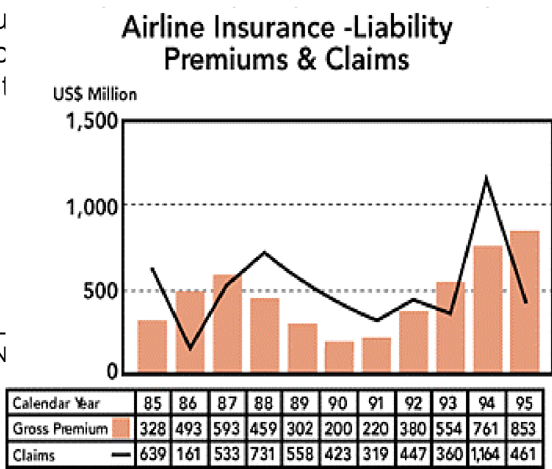


Figure 5-5: Variation of Insurance rates taking into account hull and liability ***[Ref. 162]***

5.2.3.9 It can be seen that:

- liability claims exceed liability gross premiums.
- there is little correlation between premiums and claims.
- the variation in premiums and claims demonstrates the volatility of the airline insurance market.

5.2.3.10 The variation of premiums and the lack of a correlation to claims makes it difficult to use insurance costs as a measure of the benefit of safety related measures. It is also true, as shown in Figure 5-3, that insurance costs represent a small fraction of the total operating costs. Hence, it is concluded that the main value of enhanced safety measures is to maintain an acceptable level of safety thereby to maintain passenger confidence in the industry.

5.2.3.11 Efforts in data collection and in simulations are required so that the contributions of datalink to the SRC objectives can be properly assessed.

5.2.4 Capacity

General objective

5.2.4.1 The main objective is that future ATM applications should accommodate in 2012-2015 twice the demand of 2000-2002, without creating undue ATM delays.

5.2.4.2 An undue ATM delay is a delay in excess of 1 min per flight in average. This figure was calculated by EUROCONTROL as being, based on cost of 40,00 € per minute, the average delay at which the additional cost of delay plus the cost of ATM (based on en-route charges) would be a minimum on a EUROCONTROL wide basis.

5.2.4.3 ATM delays arise from constraints at airports and in terminal and en-route airspace. Table 5-8 lists the airports at which there are the greatest constraints showing the average ATFM delay and the split of the delay attributable to ATC capacity constraints and poor weather.

Airport	Total ATFM delay (mins)	Traffic departure (per day)	Delay due to ATC capacity	Delay due to weather
Frankfurt	1.09	231	10%	26%
Athens	0.76	93	84%	1%
Amsterdam	0.70	214	3%	72%
London Heathrow	0.49	234	14%	88%
Paris CDG	0.49	261	2%	78%
Zurich	0.44	158	41%	51%
Milan MXP	0.40	126	7%	24%
Barcelona	0.32	129	*	*
Madrid	0.28	181	*	*
Brussels	0.21	159	*	*

Basle/Mulhouse	0.20	55	*	*
Heraklion	0.14	22	*	*
London Gatwick	0.13	130	*	*
Munich	0.10	157	*	*
Paris Orly	0.08	123	*	*
Vienna	0.07	102	*	*
Hamburg	0.06	75	*	*
Nice	0.06	78	*	*

* *unavailable statistics.*

Table 5-8: List of most constrained Airports ***[Ref. 157]***

5.2.4.4 It can be seen that both ATC capacity constraints and poor weather contribute significantly to the causes of delay.

5.2.4.5 Table 5-9 lists the sectors which cause most delay within ECAC airspace and which must therefore be operating at or near capacity.

Sector ID	ACC	En-route delays (mins) (as in summer 2000)
LSAZUP2	Zurich	573325
EBMAWSL	Maastricht	485308
EDUUFFM	Karlsruhe	474591
EDUUWUR	Karlsruhe	441061
LECMDGO	Madrid	350392
EGTTLUE	London	331223
LIPPNU6	Padova	324771
MERUE	Paris	323457
EGTTS14	London	277047
LFEUE	Reims	275903
LSAGISE	Geneva	275722
LIPPNL6	Padova	268422
LSAGKU6	Geneva	233932
EHDELMD	Maastricht	224777
LSAZESL	Zurich	220207
EBMALNL	Maastricht	205875
EBMALUX	Maastricht	198030
LIPPSL6	Padova	187859
LFMYY	Marseille	171184
LFMNNR	Marseille	160833

Table 5-9: List of most constrained Sectors *[Ref. 157]*

5.2.4.6 It is concluded that a substantial number of sectors in core ECAC airspace are already operating at or near capacity during busy traffic periods.

5.2.4.7 The figures presented above show the average delay. The average is quite low because the majority of flights leave on time. However, for flights which are delayed, the actual length of delay can become long leading to further “knock on” disruption of aircraft operations. The average delay per delayed flight is illustrated in Figure 5-6.

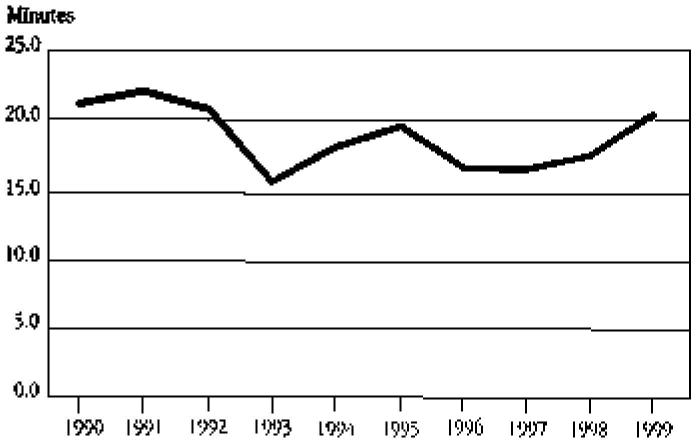


Figure 5-6: European Air Traffic Control Average Delay per Delayed flights

5.2.4.8 This long delay per delayed flight is another indicator of a system at or near capacity since, once an aircraft becomes delayed, it is difficult to find and re-assign a new slot.

5.2.4.9 Table 5-10 shows the annual cost of delays within the ECAC area.

	Delay(min)	Unit cost (Euro)	Total cost (million Euro)
ATFM delays	24 million	40-66	960-1584
Reactionary delays	12 million	28	336
Total	**36 million**		**1296-1920**

Table 5-10: Cost of en-route ATFM delays *[Ref. 106]*

5.2.4.10 Increasing delay is a symptom of airports and sectors operating near to capacity. The shortage of capacity has an even more significant effect on air transport in that it prevents new flights being introduced. Hence there is an overall quenching of demand which will get worse as the demand increases. Various attempts have been made to quantify the value to the industry of an extra flight. One approach calculates the value of an extra flight as the excess contribution to overhead recovery arising from performing an extra flight. The calculation requires data on airline economics and results in a value in the range 1000 – 1600 EURO/flight (1998 values). AEA used a different basis for calculation which resulted in a value of 1800 EURO per fight. Other estimates have ranged from 300 EURO to 3000 EURO.

5.2.5 Flight efficiency

5.2.5.1 Flight Efficiency results from the ability for an aircraft to operate the shortest route, subject to adjustment to take wind into account at the optimum flight level.

5.2.5.2 It is reasonable to assume that the highest expectations concern flight efficiency benefits in the Terminal, Oceanic, Remote and Airport environments. Indeed, flight efficiency in the European en-route airspace has reached or is planned to reach rather high levels through the following measures: a route network (ARN V4) coming closer to great circle distances; increasing use of EATMP which reduces delays in the air to the maximum; introduction of RVSM in 2002; and of RNP RNAV by 2010.

5.2.5.3 Table 5-11 shows the impact of inefficient routes.

Mean route distance (Km)	Total flights	Total Great Circle distance (Km)	Cumulative route extension (Km)	Cumulative extra hours (hrs.)	Cost of extra hours (USD)
250	1850	462500	53650	60.35	182800
350	2500	875000	97750	109.96	333068
450	2550	147500	109013	122.62	371427
550	1800	990000	84150	94.66	286716
650	1250	812500	77187	86.83	262993
750	900	675000	55350	62.26	188588
850	600	510000	49980	56.22	170292
950	550	522500	42323	47.61	144201
1050	450	472500	37800	42.52	128792
1150	400	460000	36800	41.39	125370
1250	270	437500	35000	39.37	121069
1350	250	324000	25920	29.16	88325
1450	270	391500	31320	35.23	106712

Table 5-11: Current Route Inefficiency costs on a typical day *[Ref. 158 & 163]*

5.2.5.4 The figures are based on data obtained from PRR5 Chapter 6 and assume a uniform distribution for route extension over the ranges of route distance provided. From the available data for 15th October 2001, the average inefficiencies and costs are calculated for routes between 200 km and 1100 km (see 6.2.3 in PRR5). A sample of 43 jet and turboprop aircraft was used for this estimation, assuming an average aircraft speed of Mach 0.81 (480 Knots or 889Km/h) and an average cost per block hour of $3029. The cumulative extra costs for this sample are estimated at $2.51M.

5.2.5.5 The figures obtained are based on worldwide traffic profiles rather than those more appropriate to Europe. Using a traffic sample based on European movements, a cost for a typical day of 1.64MEURO is obtained. This is less than the figure obtained in IATA calculations of 1.98MEURO per day. However, it should be noted that the data presented for horizontal route extensions in PRR5 takes into account flight levels greater than 5000ft and in doing so excludes any further contribution due to low level holding. Hence the actual figure would be expected to be closer to the IATA calculation.

5.2.5.6 In conclusion, the cost of route inefficiencies is estimated to be somewhere in the range 1.6MEURO to 2MEURO per day (equivalent to 400MEURO to 500MEURO per annum assuming 250 typical “busy” days).

5.2.6 Cost effectiveness

5.2.6.1 Cost effectiveness is measured as the means to reduce the cost of the ATS function which, in the present case, includes both the costs of the ground segment and of the onboard segment.

On board segment

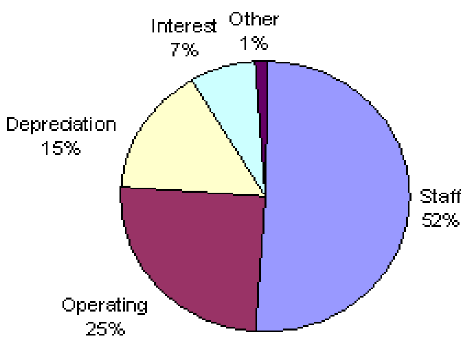
5.2.6.2 The major driver is the avionics cost. The highest cost levels are reached where the ATM application requires fitting new systems on a large majority of aircraft. This would require grounding existing fleet for retrofit, with a total cost equal to the sum of the cost of the new system, service bulletins, manpower and cost of grounding (net cost of loss of business, or cost of leasing of replacement aircraft).

5.2.6.3 The alternative to an obligation to retrofit large numbers of aircraft is to allow for long timescales (sufficient to allow for natural retirement of old aircraft types), or to segregate airspace, or to combine both solutions, which always negatively impacts on capacity or on flight efficiency.

5.2.6.4 These issues will be investigated in more detail in Phase 2 of the study.

Ground segment

5.2.6.5 The second area for cost effectiveness is the ground cost of the ATM provision. Figure 5-7 illustrates the cost of ATM for states participating in the en-route charges system.



Cost breakdown by Type	Yearly cost in Europe (Meuro)
Staff	1 830
Operating	892
Depreciation	535
Interest	256
Other	49
Total	3 562

Figure 5-7: Cost of ATM services in States participating in route charges system *[Ref. 106]*

5.2.6.6 The costs totalled 3.6 billion € per annum for the EUROCONTROL en-route area plus approximately 1,3 billion € per annum for the combined EUROCONTROL Terminal areas plus the cost of the airside of the airports of Europe (cost unknown).

5.2.6.7 Figure 5-8 shows the variation of costs from state to state.

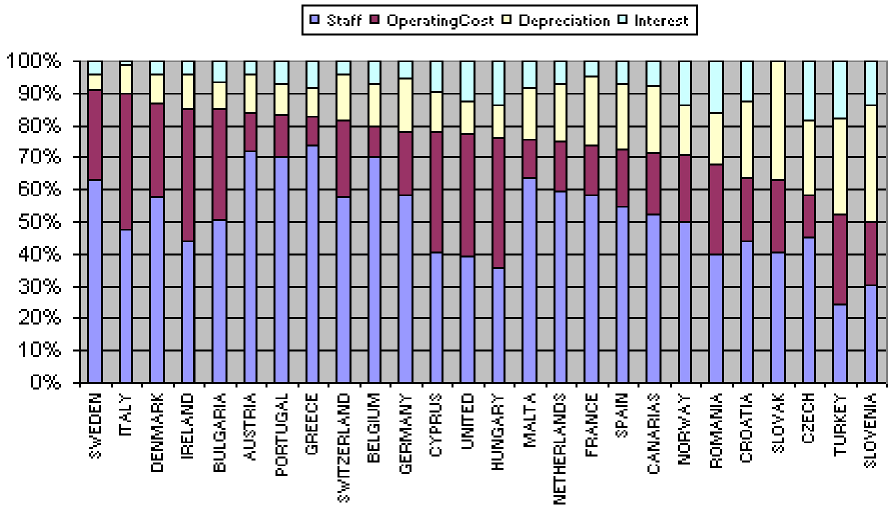


Figure 5-8: Breakdown of ATM costs per State *[Ref. 106]*

5.2.6.8 More recent figures for the staff contribution are shown in Figure 5-8.

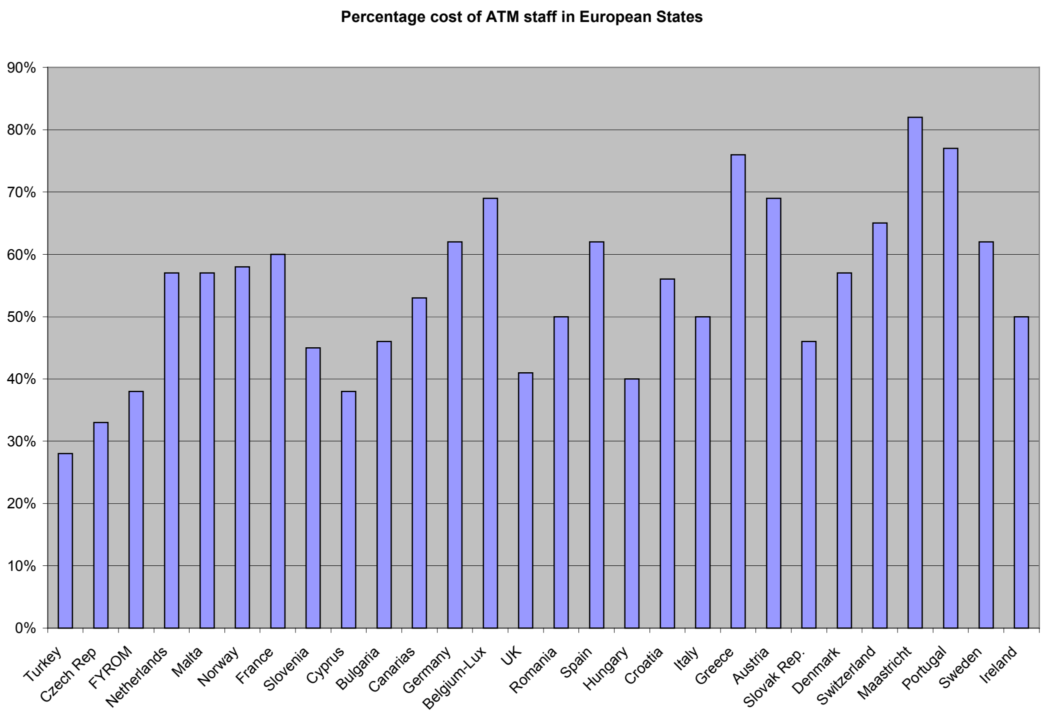


Figure 5-9: Costs related to ATM staff per State [Ref. 158]

5.2.6.9 Expenses related to normal operating expenditure and cost of ATM staff both as a percentage of the total cost are as follows:

State	Operating Costs	Staff Cost contribution	State	Operating Costs	Staff Cost contribution
Sweden	91%	61%	Hungary	75%	36%
Italy	89%	48%	Malta	74%	62%
Denmark	87%	58%	Netherlands	74%	59%
Ireland	85%	45%	France	72%	58%
Bulgaria	85%	50%	Spain	71%	55%
Austria	84%	71%	Canaries	70%	52%
Portugal	84%	70%	Norway	70%	50%
Greece	83%	72%	Romania	68%	40%
Switzerland	81%	58%	Croatia	64%	44%
Belgium	79%	70%	Slovak rep.	63%	40%
Germany	78%	58%	Czech Rep	58%	45%
Cyprus	78%	40%	Turkey	52%	25%
United Kingdom	77%	40%	Slovenia	49%	30%

Table 5-12: Breakdown of operating and staff costs per state [Ref. 158]

5.2.6.10 Although there is some variation, typically 60 % of the en-route and terminal costs are made-up of staff costs and in particular of controllers costs. The laws of diminishing returns suggests that conventional methods for the delivery of capacity, based on creating new sectors, will reach their limits and that the cost of manpower would grow exponentially.

5.2.6.11 15 % of the en-route and terminal costs correspond to the depreciation of assets. The respective shares of Navigation, Communication, Surveillance and of ATM assets are unknown but there are expectation that Datalink has the capacity to reduce part of the infrastructure cost.

5.3 Impact of doing nothing

5.3.1 A “do nothing” scenario is the theoretical scenario where nothing would be done to improve safety, capacity, flight efficiency or cost-effectiveness, as the existing concepts, applications and resources would be kept unchanged.

5.3.2 As traffic levels come back, capacity problem would come back very soon, as the elasticity of delays to un-accommodated demand is around 1 to 5.

5.3.3 In 1999, the lack of capacity created 43 million or primary ATFM delays, for a total cost for the airspace users of 1.500 million €. This figure is based on the IATA figure of 22,00 € per minute of delay.

5.3.4 This cost did not include the cost of loss of business, cancellations, indemnities etc.

5.3.5 According to PRR2 (November 1999), the lack of capacity had a cost to the passengers estimated at 4.200 million €. The total cost (airspace users plus passengers) therefore exceeded 5.700 million €.

5.3.6 PRR4 (April 2001) values airspace users delay at 40,00-60,00 € per minute (primary delays) and at 28,00 € (reactionary delays) making the total cost even higher than 5.700 million €.

5.3.7 The consequences of such delays in 1999 were extremely severe, and hit well beyond the aviation community.

5.3.8 A slight delay in implementation of new concepts, application or in developing new resources would bring aviation very fast back to the unacceptable situation of 1999.

5.3.9 The statistics presented in Section 5.2 indicate that:

- traffic is forecast to grow by approximately 0.5M/annum from its 2000 level of 6M.
- the cost of delay is approximately 1500 MEURO/annum at current traffic levels.
- ATM charges are currently 5000 MEURO/annum of which 2000 MEURO/annum is the cost of staff
- the value of additional flights to the airline industry is approximately 1500 EURO/flight, although the basis for this calculation is open to question. Airlines prefer the viewpoint that capacity should increase in order to avoid rapid escalation of delays.
- The cost of inefficient routing is approximately 400- 500MEURO/annum.

5.3.10 As traffic grows within the current infrastructure, it is likely that:

- part of the growth in traffic could be accommodated via short term measures such as re-sectorisation and diversion into less busy airspace. It is possible that a further growth of 50% could be accommodated by such means, such that traffic levels predicted for 2010 could be sustained.
- however, airports and sectors within the core of Europe are already capacity limited at busy times of the day and hence it is likely that delays will increase and traffic growth within core Europe become constrained before 2010.
- overall, growth will be severely constrained from 2010 onwards.

5.3.11 In planning developments for the future, the primary goal is to provide sufficient capacity to cope with demand. Otherwise the cost of delays will increase rapidly and the total cost to the airlines will very quickly rise to the level of 5700MEURO experienced in 1999.

5.3.12 Thereafter, the priority is to focus on means to improve cost effectiveness and flight efficiency.:

- In en-route and terminal areas, it seems reasonable to assume that priority should be given to measures which allow a greater volume of traffic to be handled without increasing the number of controllers (sectors) required. Current staff costs are 2000MEURO/annum (or 333EURO/flight) hence keeping this constant is equivalent to a total benefit which increases by 170MEURO per year. This neglects any other cost saving measures such as reducing the level of investment in ground infrastructure.

- Assuming that the measures introduced can reduce route inefficiency to half of the current level, the benefit is 200MEURO at current traffic levels increasing by 16MEURO per year as traffic increases. Note that much of this benefit could be claimed by RNAV implementation.
- Although one could assume that the delay per flight could stay at current levels, it seems reasonable to require that sufficient capacity is provided to reduce the average delay. Assuming that the average delay per flight is reduced by 25%, the benefit is 375MEURO/annum at current traffic levels increasing by 30MEURO per year as traffic increases.

5.3.13 Taking these measures together, the total estimate of the benefits in terms of reduced operating costs, available for ATC enhancement measures is 575MEURO/annum at current traffic levels increasing by 216MEURO/annum with the year on year traffic increase. This is illustrated in Figure 5-10.

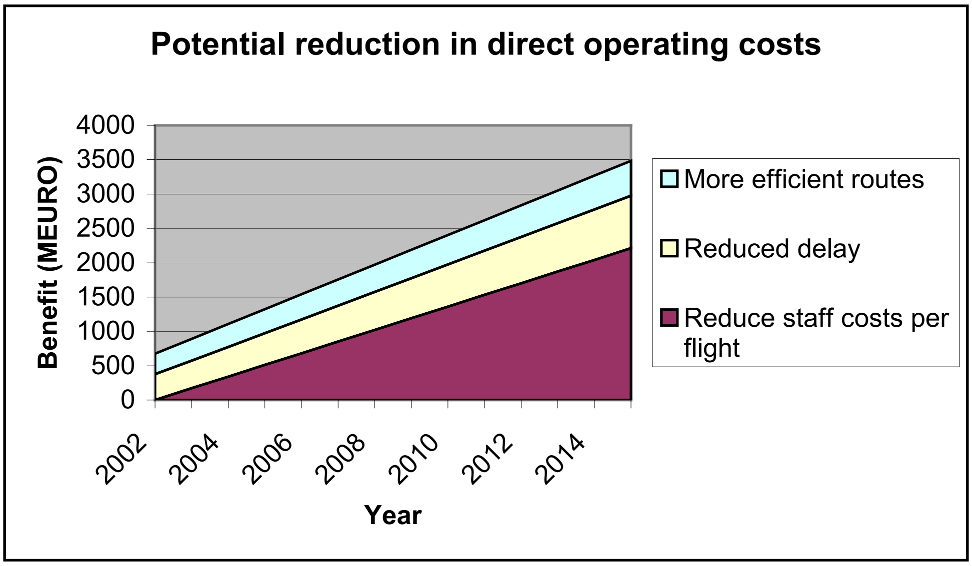


Figure 5-10: Potential reduction in direct operating costs (ECAC region)

5.3.14 Note that initially the greatest benefits arise from reduced delay and more efficient routes. However, as traffic grows the greatest potential reduction in direct operating costs arises from maintaining the current level of controllers. This implies that priority should be given to measures that provide additional capacity without increasing the number of sectors.

5.4 Development options

5.4.1 Objectives for change

5.4.1.1 The key objectives for future development of ATM are:

- to maintain or increase current levels of safety;
- to meet future demand;

- to minimise the costs associated with ATM including the cost of providing the ATM service and the costs associated with inefficient trajectories;
- from the airline perspective, to increase the flexibility for operating flights.

5.4.1.2 This section identifies and analyses options for development and change to ATM focussing firstly on providing a step change in available capacity supporting a greater level of direct routing. The implications for maintaining safety are then discussed.

5.4.2 Options for change

Geographic coverage

5.4.2.1 We take the assumption that, on a long time basis (e.g. 2012-2015) the demand will grow equally in each categories of European airspace: en-route, terminal, oceanic, remote, airport. Note also the emphasis of the analysis will be to provide sufficient airspace capacity so that the limitation on traffic growth becomes availability of runway capacity. It is assumed that runway capacity will grow in pace with traffic demand but it is important to realise that Europe must make significant investment to ensure that sufficient new runways are built.

5.4.2.2 The challenge of creating sufficient capacity will be greatest in the “Core Area of Europe”, where density of traffic is at its highest today and where present ATM concept start showing their limits.

5.4.2.3 The “Core Area of Europe” is composed of France, United Kingdom, Benelux, Germany, Switzerland and north of Italy. Of course, as traffic grows, the size of the Core Area will grow in absolute terms and the complexity of the existing Core Area will spread over a larger airspace.

Origins of capacity

5.4.2.4 Additional capacity may result from:

- A reduction in controllers’ workload, the controller still performing substantially the same tasks and being vested with substantially the same responsibilities as today. The reduction in controller workload then makes it possible to open controlled airspace to a larger number of aircraft than is possible today. A typical example consists of replacing R/T communications “by the click of the mouse” (Link 2000+).
- A reduction in the separation between aircraft, not at the expense of safety and without adding burden to the controller. Typical examples are the introduction of RVSM (Reduced Vertical Separation Minima) or the utilisation of RNP RNAV compliant aircraft in 2010.
- Partial or total delegation of the responsibility of separation by the controller to the pilot to the extend and provided that this delegation of separation is capable to create more capacity (the alternative –or trade off- being the reduction of the cost of ATM function).

Anticipating capacity gains

5.4.2.5 It is remarkable that very few activities have been carried out to quantify with reasonable accuracy the increase in capacity linked to a reduction in controllers’ workload or to reduced separation between aircraft.

5.4.2.6 For the time being, two Fast Time Simulations (FTS) on Enhanced Surveillance have concluded that a potential 5% increase in the en-route airspace of the Core Area if the en-route controller have an immediate access to 3 CAPs (Control Access Parameters: ground speed, magnetic heading, selected altitude) and about 75% of the aircraft are equipped. The conclusion came from a FTS of the Karlsruhe airspace and was cross-checked by another FTS of the Maastricht Upper Airspace.

5.4.2.7 Another FTS of the Karlsruhe airspace has concluded that a potential 13% capacity gain is possible in the case of implementation of CPDLC based on Link 2000 and 75% equipage.

5.4.2.8 A Real Time Simulation (RTS) called Escapade, concluded that the TMA controller could accommodate 10% more traffic based on the availability of a combination of CAPs and SAPs (System Access Parameters).

5.4.2.9 A RTS conducted in Bretigny concluded that RVSM made it possible to increase the traffic of the relevant airspace by 20% without requiring more sectors, to grow even further with re-sectorisation.

5.4.2.10 Apart from the above FTS and RTS, there is little or no material available quantifying capacity gains resulting from new concepts of operation and ATM applications. Most figures available come from experts' judgement and consensus.

5.4.2.11 The consortium therefore recommend setting-up a roadmap of FTS/RTS and trials activities with the intention to validate in due time the benefits expected from each ATM application.

5.4.3 Approach to analysis of options for provision of additional capacity

5.4.3.1 In order to provide an initial assessment of the possible impact of the various data link enabled approaches to providing more airspace capacity, a simple analysis has been carried out by the consortium. The results of this analysis are not intended to provide a precise indication of capacity enhancements and would require detailed validation through simulations. However, the intention is to provide a broad indication of the level of enhancement that might be possible with each proposed measure.

5.4.3.2 The main development trends for development of ATM are as follows:

- optimise the current control paradigm
- develop current control paradigm without delegation to pilot (multi-sector planning, 4D trajectory negotiation)
- delegate some tasks to pilot
- delegate most tasks to pilot

5.4.3.3 In addition, regardless of how aircraft are controlled, significant benefits are possible as a result of airspace re-organisation.

5.4.3.4 The motivation for airlines is to be able to take decisions on when and where to fly. Hence a definition of free flight is that the request for a particular trajectory will generally be granted unless there is some overriding (and rare) safety reason. Such a system could be supported by ground focussed trajectory negotiation or by airborne decision and ground monitoring.

5.4.3.5 Whatever the solution, the likelihood is that:

- ground holding will be necessary to control the flow rate at destination airports.
- there will be a need for sequencing onto busy runways
- some structuring of airspace will be necessary to make the tactical decision process for pilots and controllers simpler
- in the case of ATM focussed on an airborne decision process, there will be a need to uplink airspace constraints
- there will always be a need for great route restrictions in busy terminal areas.

5.4.4 Scenarios for analysis

5.4.4.1 The following scenarios have been analysed:

- Optimisation of current control paradigm in which the controller maintains responsibility for tactical control, the ground system provides a flight planning service, the pilot follows controller instructions and the pilot provides a monitoring function.
- Development of current control paradigm in which the controller maintains responsibility for tactical control, the ground system calculates and provides conflict free trajectories, operators request trajectories, the pilot follows controller instructions and the pilot provides a monitoring function. The planning constraints are to provide metered arrival rates at airports and minimisation of the number of conflict events presented to the controller
- Limited delegation to pilot. Use of spacing applications to transfer some of the workload to the pilot.
- Full delegation to pilot. This involves the transfer of separation responsibility to pilot.

5.4.4.2 The analysis is first presented in relation to en-route and remote airspace. The theme is then developed for terminal and airport surface regions.

5.4.5 Analysis approach

5.4.5.1 A simple model of the control task has been developed based on the number of interactions experienced by aircraft flying into regions of varying traffic density.

5.4.5.2 The control task consists of:

- communication of trajectory changes;
- monitoring pairs of aircraft within a defined flying time of each other;
- conflict resolution action for pairs of aircraft passing within a certain distance of each other;
- communication of conflict resolution actions.

5.4.5.3 Other tasks arise because of sectorisation:

- air/ground communication for call in/hand off
- communication for controller/controller coordination

5.4.5.4 The model is not intended to be a detailed human factors model of the control task. Rather it is intended to support sensitivity analysis so as to identify those measures likely to have a significant impact on capacity and route efficiency.

5.4.5.5 The model will be used to contrast the situation where the controller and pilot have access to the same information and can carry out the same tasks. The purpose is to look at the impact of distributing tasks to pilot.

5.4.6 Optimisation of current control paradigm

5.4.6.1 Figure 5-11 shows the distribution of workload for typical en-route sectors. The example is taken from the simulations carried out in the Karlsruhe region which were focussed on assessing the benefits of introducing Mode S SSR. The example is used to illustrate, more generally, the distribution of controller tasks in en-route airspace. Of course, the distribution will change dependent on the airspace – however, the example chosen is sufficiently typical to allow broad conclusions to be made.

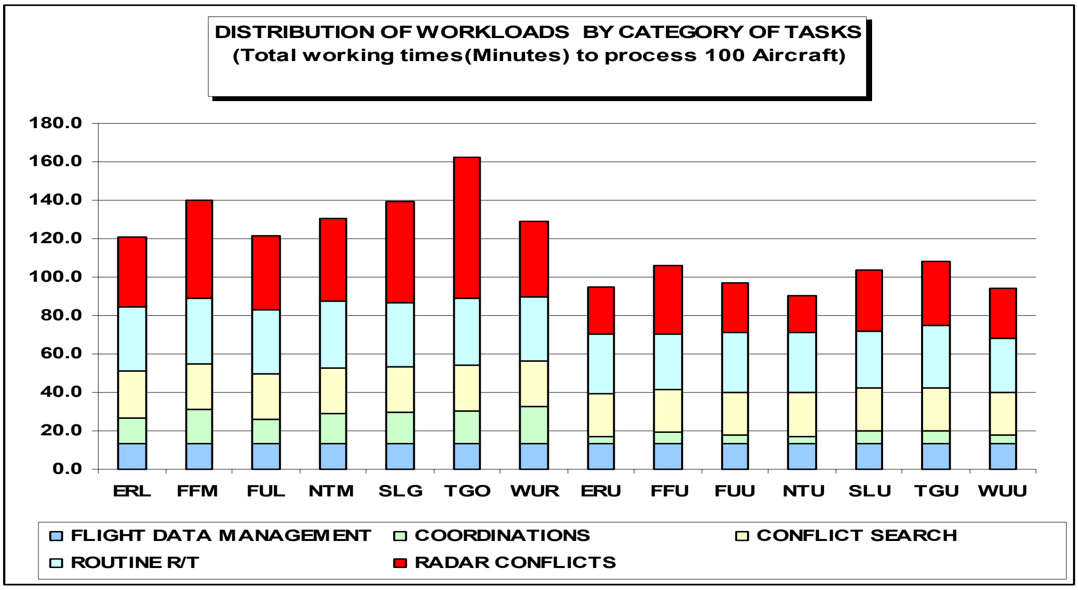


Figure 5-11: Distribution of Controller Workloads for an area in Core European Airspace *[Ref. 165]*

5.4.6.2 The controllers time is typically divided as follows:

- Conflict Search: Approximately 20 minutes per 100 aircraft is spent monitoring pairs of aircraft within defined flying time of each other. Since the task consists of monitoring pairs of aircraft, this element of workload is assumed to scale in proportion to the number of aircraft pairs in the sector.
- Radar conflicts: Approximately 35 minutes per 100 aircraft is spent on conflict resolution tasks for pairs of aircraft passing within a certain distance of each

other. Since the task consists of conflicts between pairs of aircraft, this element of workload is assumed to scale in proportion to the number of aircraft pairs in the sector.

- Routine communication. Approximately 30 minutes per 100 aircraft is spent on routine communication tasks. These tasks are divided into:
  - air/ground communication for call in/hand off. It is assumed that 50% of routine communication time is spent on this task. The task depends on how often an aircraft crosses the sector boundary and hence scales in proportion to the number of aircraft in the sector divided by the time spent in the sector.
  - other communication eg heading and flight level changes. It is assumed that 50% of routine communication time is spent on this task. This task depends on the number of aircraft in the sector.
- Coordinations. Approximately 10 minutes per 100 aircraft is spent on communication for controller/controller coordination. This task depends on how often an aircraft crosses the sector boundary and hence scales in proportion to the number of aircraft in the sector divided by the time spent in the sector.
- Flight data management. Approximately 10 minutes per 100 aircraft is spent carrying out flight data management. This task scales according to the number of aircraft in the sector.

5.4.6.3 The total time required to control 100 aircraft is 105 minutes. In one hour, the controller can therefore control a maximum of 57 aircraft (assuming that 60 minutes per hour is available for control tasks). Assuming a typical en-route sector of size 100 nm by 100 nm with aircraft flying at 500 knots, each aircraft spends on average 12 minutes in the sector. Hence the average number of aircraft in a sector at any one time is approximately 12.

5.4.6.4 Measures that could be taken to improve the situation are described below.

Improve quality of downlinked data

5.4.6.5 By improving the surveillance picture by downlinking aircraft data, the controller gains a better picture of an aircraft's position and intent. This can primarily impact on the monitoring workload and may also reduce the rate at which conflict resolution is necessary. Assuming that the monitoring element of workload can be decreased by 25%, the overall increase in capacity derived from the simple model is 7%.

Automation of communication

5.4.6.6 Data link has the potential for reducing the time spent on communication tasks. Assuming that a reduction of communication workload by 50% is possible, the potential increase in capacity is 12.5%.

Conflict probe

5.4.6.7 A conflict probe would make possible further reductions in monitoring workload. Assuming that monitoring workload can be reduced by 50%, the increase in capacity is 12%.

Conflict advisories tool

5.4.6.8 A tool providing advice on conflict resolution actions could reduce the time taken to solve conflicts. Assuming that this reduces conflict resolution workload by 50%, the increase in capacity is 16%.

Combined measures

5.4.6.9 Taking a combined case of automation of communication, conflict probe and conflict advisories tool, the increase in capacity is 45%. Further increases could be obtained by improving the efficiency of inter-sector coordination.

5.4.6.10 Within the limits of the simple model presented here, it is possible to conclude that a significant capacity increase is possible, but that, even with widespread use of controller tools, it is difficult to see how an increase greater than 45% could be achieved.

5.4.6.11 Note also that the figures presented in this simple analysis are generally a little greater than the results obtained for Karlsruhe, suggesting that the model is providing an upper limit to the increase in capacity. For example, Figure 5-12 indicates that an increase in capacity of up to 9.2% could be achieved by providing assistance to the radar conflict workload task compared with up to 16% in the simple model.

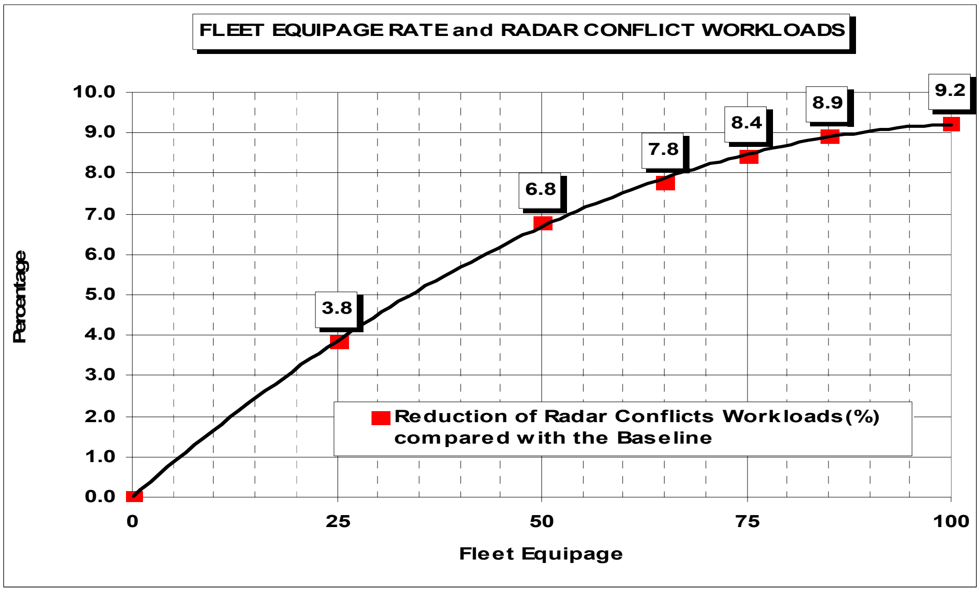


Figure 5-12: Sensitivity Analysis on Fleet Equipage and Controller Workloads ***[Ref. 165]***

5.4.6.12 The limit to the possible capacity increase is imposed by the increase in traffic volume which, because of the dependence on the number of pairs in the sector, tends to increase the monitoring and conflict resolution workload rapidly, negating the impact of reductions in other elements of the controller workload.

5.4.6.13 Successive automation of the controller's task can probably meet many of core en-route sector demand requirements in the short term (ie up to 2010) but there is still likely to be a shortfall in the busiest en-route sectors. (note that although capacity has doubled in some en-route sectors, some sectors are already capacity constrained and hence an increase by more than two is required).

5.4.6.14 Note also that further increases in capacity could be obtained by reducing the sector size but this has the negative impact of:

- requiring more sectors (more cost)
- increasing coordination workload
- reducing the geographical areas over which conflict resolution advisories can be given, reducing their efficiency and probably leading to a further increase in coordination workload
- There is a limit to this: The size of sector has to be sufficiently large to ensure that the 'control' time is a significant proportion of the hand-over time. Also there are limitations on frequencies.

5.4.6.15 A general disadvantage is that maintenance of the current control paradigm places more and more emphasis on a centralised ground-based system and throughput is particularly vulnerable to failures in this system.

5.4.7 Conflict free trajectories

5.4.7.1 Further increases in capacity are possible by introducing conflict free trajectories. This has the potential to reduce the conflict resolution workload further but it is debatable whether there would be any significant impact on monitoring workload since the controller is still taking responsibility for separation. Using the previous model and assuming that conflict resolution workload can be reduced by 90%, a capacity increase of 79% could be produced.

5.4.7.2 For en-route region, Table 5-13 shows the ATM applications required to support progressive development of the current control paradigm leading to conflict free trajectories.

			Development of current concept				
#	ATM application	Timescale (intro. – wide usage)	Improve quality of downlinked data	Introduce conflict probe	Introduce conflict advisories tool	Automate communication	Conflict free trajectories
APP1a	Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller	2004 – 2005	y	y	y	y	y
APP1b	Enhanced surveillance in terminal and en-route airspace providing a w ider range of DAPs	2005 – 2007		y	y	y	y
APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace	2005 – 2007		y	y	y	y
APP2a	Pilot preferences data link	2006 – 2007				y	y
APP2b	Strategic controller/pilot messages	2002 – 2004				y	y
APP2c	Support for increased automation	2008 – 2010				y	y
APP2d	Trajectory negotiation	2009 – 2012					y
		% increase in capacity	7	12	27	45	79
		Approximate timescale	2004-2005	2005-2007	2005-2007	2008-2010	2009-2013

Table 5-13: ATM applications required to provide development of current control paradigm

5.4.7.3 Figure 5-13 shows the comparison of the potential increase in capacity against demand for progressive development of the current control paradigm. The graph shows the medium traffic forecast level taken from Figure 5-1 with error bars indicating the high and low forecast levels. The capacity figures are taken from Table 5-13. The “late” line assumes the capacity enhancement is provided at the latest timescale shown in Table 5-13. The “early” line shows the earliest timescale from Table 5-13.

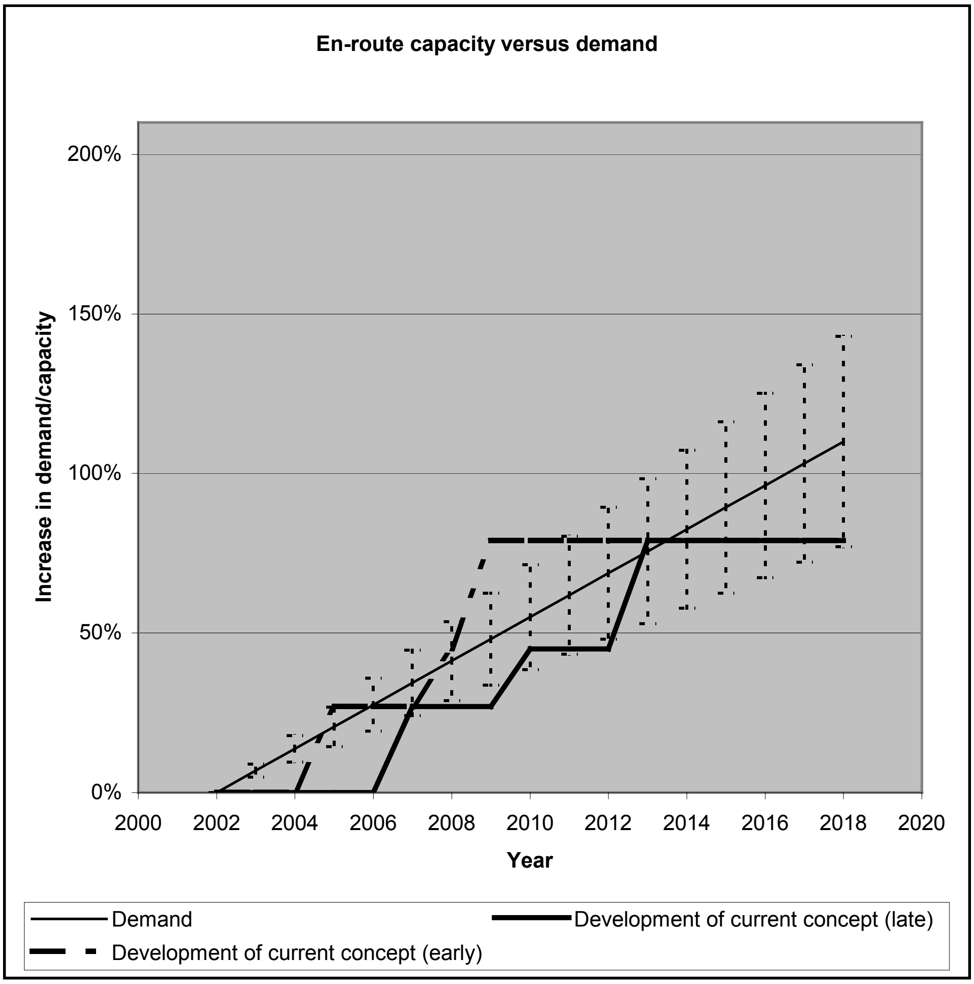


Figure 5-13: Development of current concept versus demand

5.4.7.4 Early implementation of the appropriate ATM applications has the potential to meet demand in the first period, but the potential for further increases in capacity is limited and the demand cannot be met in the period 2010 to 2015.

5.4.8 Limited delegation to pilot

5.4.8.1 A further development option is to delegate some responsibility to the pilot whilst maintaining responsibility for separation with the controller. The benefit is that much of the communication task is removed since the pilot takes responsibility for heading and altitude changes. Note that not all of the communication task is removed since there will be a need for the controller to issue delegation instructions.

5.4.8.2 Consider firstly delegating spacing tasks to the pilot in addition to the combined measures presented in paragraph 5.4.6.9. Assuming that this halves the communication work load, this could increase capacity by 54%.

5.4.8.3 If the level of delegation is increased such that the pilot takes limited responsibility for separation, then a reduction in monitoring and conflict resolution workload may be possible. Assuming that these elements of workload can be reduced by 50%, then a capacity increase by 93% may be possible.

5.4.8.4 A real time simulation of delegated spacing was carried out as part of the FREER project. Figure 5-14 shows the airspace region that was simulated.

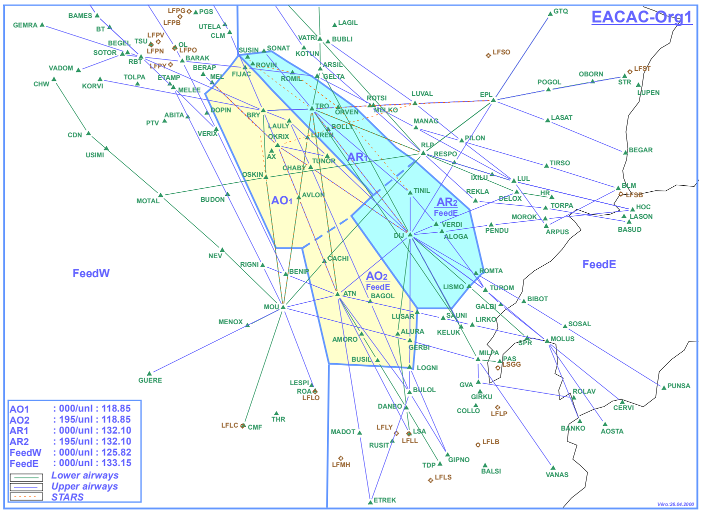


Figure 5-14: Airspace domain for FREER real time simulations

5.4.8.5 Figure 5-15 shows the results of the simulation.

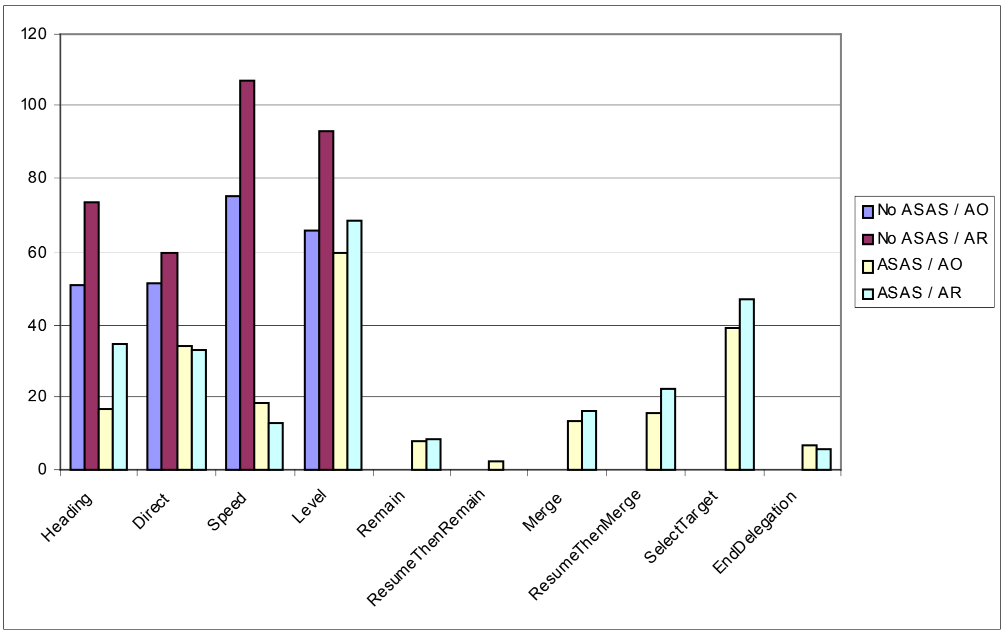


Figure 5-15: FREER real time simulation results

5.4.8.6 The use of spacing results in a significant decrease in the use of flight path change instructions (heading, direct, speed, level in the figure). This is partially compensated by the need to provide instructions related to the spacing manoeuvre (remain, resume then remain, merge, resume then merge, select target, end delegation). However, the overall impact is a significant reduction in communication workload.

5.4.9 Delegation to pilot

5.4.9.1 In this scenario, it is assumed that ATM is organised quite differently with tactical separation tasks assigned to the pilot. It is assumed that the aircraft has a good picture of other aircraft's position and intent.

5.4.9.2 To estimate the time taken by a pilot to carry out the ATM tasks, the following assumptions are made:

- The pilot monitors the positions of other aircraft with respect to his own position rather than all pairs within a region of airspace equivalent to the size of the en-route sector of the previous example. Hence for monitoring and conflict resolution, the pilot has less workload than in the previous example by a factor equal to the number of aircraft in the sector.
- The pilot has no need to coordinate with adjacent sectors and hence the controller/controller coordination workload and flight data management does not apply.
- It is assumed that there is no sector structure and hence there is no need to perform call in and hand off tasks although there may still be a need for occasional communication with the ground. In this simple example, it is assumed that this aspect of workload can be reduced by 75% through automation and a reduction in the number of sectors.
- It is also assumed that the pilot takes responsibility for heading and level changes and hence the need for other communication is minimised.

5.4.9.3 Taking these assumptions into account, for the baseline sector, the pilot would spend 2.9 minutes per hour carrying out ATM related tasks.

5.4.9.4 The capacity in this example is set by the need to minimise the impact on the pilot's other tasks associated with flying the aircraft. Assuming that it is reasonable in en-route airspace for a pilot to spend up to 5 minutes on ATM tasks, then it can be seen that there is a great potential for increased capacity, even without additional measures. The simple calculation indicates that a capacity increase of 71% relative to the baseline could be obtained. (Note that this figure is extremely sensitive to the assumption of the time that a pilot can dedicate to ATM related tasks).

5.4.9.5 Further increases in capacity could result from provision of cockpit tools to assist in monitoring and conflict resolution workload. If it is assumed that these can reduce the time taken to carry out the monitoring and conflict resolution tasks by 25%, then the increase in capacity is over 200%, sufficient to support en-route traffic density in core en-route airspace in 2015 and to provide a potential decrease in the number of sectors required.

5.4.9.6 The key result is that increase in capacity is larger than for controller example because there is not the additional dependence on number of aircraft in the sector.

5.4.9.7 The concept is also more suited to efficient routes because each pilot is dealing with a single conflict point at a time and the location in space is not important (ie there is no need to structure routes to make resolution of conflicts easier). Also, the “sector” effectively moves with the aircraft.

5.4.9.8 The following concerns are raised by this concept:

- provision of suitable CNS infrastructure and tools to give the pilot the best picture. Note that, in order to be in the same position as the controller of an en-route sector, the pilot will need a similar picture extending to aircraft within at least 80nm.
- the pilot may not be able to solve the conflict as quickly as controller
- the pilot may not provide the most efficient resolution because he cannot coordinate with adjoining areas. This is mitigated by providing clear objectives for arrival times at key parts in airspace and giving the pilot the largest possible geographical view.
- clear rules of the air need to be defined for resolving conflicts
- compared with the viewpoint of a controller, a pilot may feel less secure about other aircraft in adjoining flight levels (and hence require proportionately more monitoring workload).

5.4.9.9 This scenario is likely to be effective if there is little impact on the pilot’s other tasks. Hence:

- the number of conflict resolution tasks presented to pilot must be small;
- when resolving a conflict, only one other aircraft should be involved, the aircraft intent should be clear and the rules for resolution should be clear and unambiguous[11];
- the number of aircraft that have to be monitored as being potentially in conflict should be small;
- there should be plenty of time to resolve any conflicts.

5.4.9.10 The role of the ground system in this scenario needs to be determined by further research[12]. Possible roles include:

- coordination of trajectories, and, in particular, determination of arrival time at the terminal area, leading to eg ground holding;

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[11] It should be noted that flight test in Swedish airspace have demonstrated good possibilities for conflict resolution with four aircrafts involved, provided that trajectory change points are exchanged between aircrafts and that the CDTI indicates conflicts as well as potential conflicts. This can also be resolved by braking multiple conflicts down into conflict pairs – each pair being solved by a single resolution manoeuvre.

[12] If TCP's are exchanged between aircraft the GND system may not have to be involved in the co-ordination.

- provision of uplink advisories on in-flight constraints;
- some form of monitoring function.

5.4.9.11 The planning constraints might be to provide metered arrival rates at airports and minimisation of number of conflict events presented to pilot by ensuring that the density of aircraft in a particular region is not too great. This information can also be filtered in the onboard display.

5.4.9.12 Table 5-14 shows the ATM applications required to support progressive introduction of delegation to pilot. Initially, it is assumed that the controller function is developed with controller tools as per the concept described in Section 5.4.6, Then spacing ATM applications add additional capacity in the period 2006 –2009. Finally, the concept moves to self-separation from 2011 onwards.

#	ATM application	Timescale (intro. – wide usage)	Improve quality of downlinked data	Introduce conflict probe	Introduce conflict advisories tool	Introduce en-route spacing	Automate communication	Introduce en-route separation	Self-separation with monitoring and resolution tools
APP1a	Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller	2004 – 2005	y	y	y	y	y	y	y
APP1b	Enhanced surveillance in terminal and en-route airspace providing a w ider range of DAPs	2005 – 2007		y	y	y	y	y	y
APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace	2005 – 2007		y	y	y	y	y	y
APP2a	Pilot preferences data link	2006 – 2007					y	y	y
APP2b	Strategic controller/pilot messages	2002 – 2004					y	y	y
APP2c	Support for increased automation	2008 – 2010					y	y	y
APP4b	Provision of full range of uplink information services	2009 – 2010							y
APP7a	Provision of information on route availability (DYNAV)	2007 – 2009							y
APP9a	Airborne spacing in en-route and terminal airspace	2006 – 2009				y	y	y	y
APP9b	Crossing and passing in en route airspace	2006 – 2009				y	y	y	y
APP10b	Airborne separation in en-route and terminal airspace	2011 – 2015						y	y
APP1a	Cluster control in ATC managed airsspace	2013 - 2018							
APP11b	Autonomous operations in FFAS	2013 – 2018							y
	% increase in capacity		7	12	27	36	54	93	>200
	Approximate timescale		2004-2005	2005-2007	2005-2007	2006-2009	2008-2010	2011-2015	2013-2018

Table 5-14: ATM applications required to support en-route capacity enhancements through increasing delegation to pilot

5.4.9.13 Figure 5-16 shows the comparison between demand and capacity for progressive delegation to pilot.

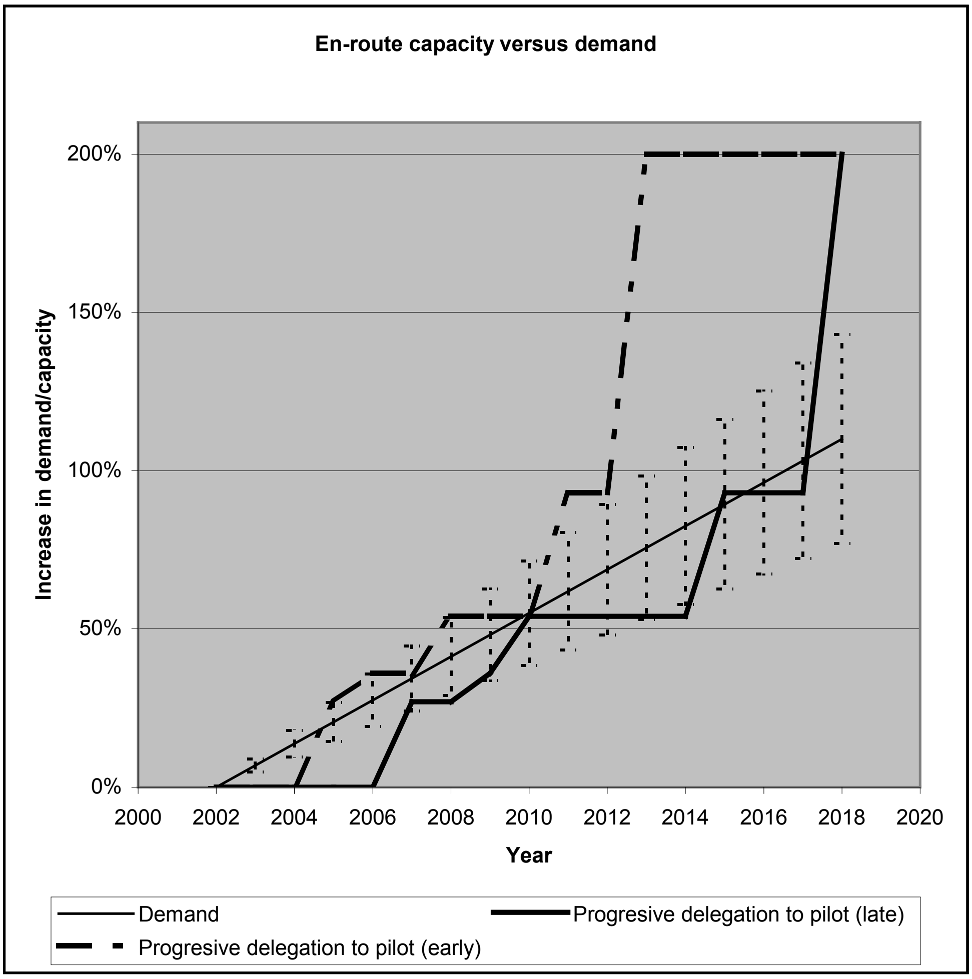


Figure 5-16: Progressive delegation to pilot versus demand

5.4.9.14 It can be seen that it is, in principle, possible to meet demand although it appears important to introduce spacing and separation ATM application as early as possible.

5.4.9.15 It is concluded that, in the early days, it is worthwhile focussing on controller tools. However, later on, it is better to focus on greater pilot autonomy with “light touch” trajectory planning, consisting of definition of arrival times at the terminal area, rather than implementing conflict free trajectory planning for flights in the en-route region.

5.4.10 Limits to delegation to pilot

5.4.10.1 Although delegation to pilot appears to offer great potential for achieving increases in capacity, concerns arise as the density of traffic increases:

- the density of traffic should be low enough to keep pilot workload within reasonable bounds. eg a possible rule of thumb is that pilot should not have to carry out more than 2 conflict resolutions per hour
- the density of traffic should be low enough to minimise the impact of resolution activity on other aircraft.

5.4.10.2 Simple calculation of traffic interactions at densities representative of core Europe in 2015 indicate that the number of conflicts is between 1 and 2 per hour for a random traffic sample. However, at densities representative of core region terminal, the number of conflicts per hour increase because:

- the density is higher;
- aircraft are manoeuvring and hence each pilot must take account of a greater number of flight levels in carrying out monitoring checks.

5.4.10.3 The result is that delegation to pilot gives greatest potential for providing capacity in en-route regions but is likely to be limited in effectiveness in very busy areas. In the context of European airspace, this is likely to be in core terminal area.

5.4.11 Terminal area

5.4.11.1 Busy terminal areas are characterised by:

- a high density of relatively slow moving, manoeuvring traffic;
- increasing structure to flows as aircraft approach or depart from airports;
- less time for a pilot to resolve conflicts since he is busy on other tasks related to the approach to or departure from an airport.

5.4.11.2 Under these conditions, the delegation to pilot scenario presented in Section 5.4.9 is less likely to be effective. Furthermore, in order to achieve the highest possible arrival rate on to a runway, ground centred organisation will be necessary. This implies that a higher level of ground centred organisation will be necessary in busy terminal areas.

5.4.11.3 Figure 5-17 shows the distribution of workload for selected TMA sectors.

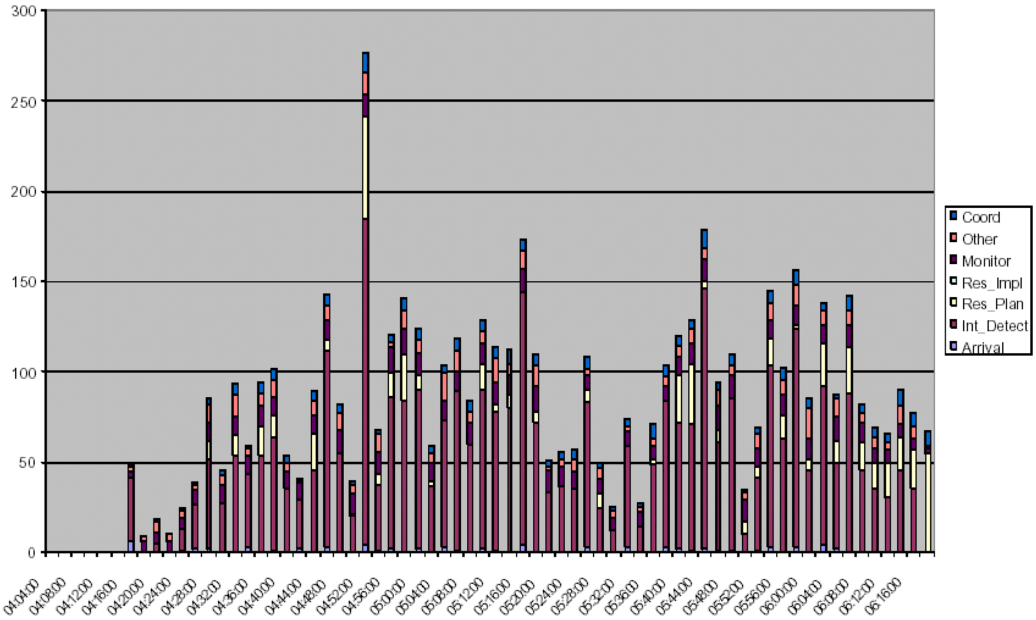
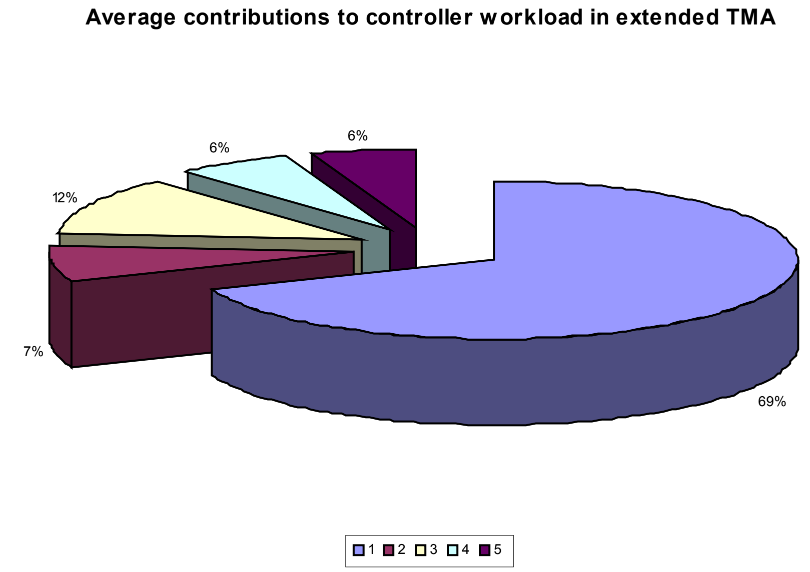


Figure 5-17: Distribution of workload for TMA sectors

5.4.11.4 The distribution of workload is very different from that used in typical en-route sectors with much of the controllers task focussed on the detection of potential conflicts (Int_detect in the above diagram).

5.4.11.5 Figure 5-18 provides an average of this data.



(1) Determining the forecast interactions of a flight
(2) Co-ordination with other control agencies
(3) Other changes to the trajectory
(4) Planning resolutions for each forecast interaction
(5) Implementing resolutions for each forecast interaction

Figure 5-18: Average distribution of workload for TMA sectors (Source: Validation report for INTEGRA metrics in EACAC)

5.4.11.6 69% of workload is spent determining interactions of a flight. Much of this results from the need to place aircraft onto defined routes within the sector structure. However, whereas previously navigation within the terminal area was limited to waypoints defined by the navigation infrastructure, the introduction of RNAV makes possible a much more flexible route structure. This makes it possible to define routes which are geographically separated and on which aircraft fly to conform to fixed arrival times on the approach path.

5.4.11.7 The proposed concept for busy terminal areas is therefore as follows:

- de-confliction of traffic using structured routes notified by the ground (or at least negotiated with ground) flown using advanced navigation capability
- controller centred control for merging and de-merging traffic assisted by controller tools and automated communication.
- airborne support via spacing to optimise flows on structured routes.

5.4.11.8 Note that a large proportion of the benefits of this concept can be attributed to the introduction of RNAV. The role of data link would include:

- notification of which routes to fly;
- downlink of airborne parameters for conformance monitoring;
- air-air broadcast to support merging and spacing operations.

5.4.12 Approach, departure and airport surface

5.4.12.1 The use of geographically separated routes within the terminal area will have the effect of moving the merging point for approach traffic closer to the approach path. Achievement of maximum capacity will depend on aircraft achieving the optimum separation on the approach path. This is a well accepted potential role for spacing ATM applications and was one of the main applications which was demonstrated in the ADS-B CBA to provide significant benefit. Figure 5-19 illustrates why the ATM application has the potential to provide benefit.

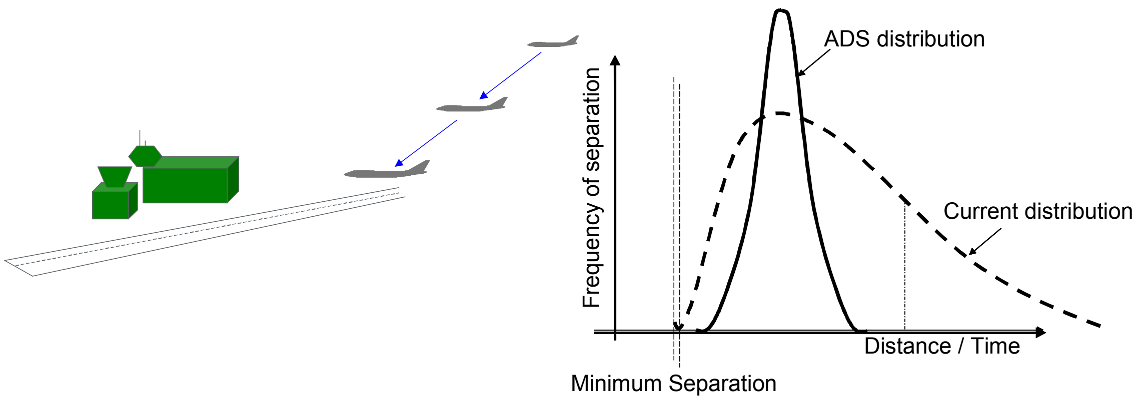


Figure 5-19: Use of airborne spacing to improve efficiency on approach path.

5.4.12.2 Current distributions on the approach path are broadly spread. The use of airborne spacing allows a much more regular spacing to be achieved near to the minimum allowed separation. The result is a higher average arrival rate. JAFTI

[115] view this application initially as a simple extension of VMC which could result in an increase arrival rate of between 1-3 landings per hour at major hub airports.

5.4.12.3 Further enhancement of arrival rate is possible by development of the concept set out above. JAFTI [115] see a development towards time based separation as being the best method of increasing arrival rates further. They also advocate the use of ATSAW ATM applications to support increased arrival rates under IMC conditions. Strictly, such usage pushes the concept towards the use of airborne separation ATM applications since the aircraft is maintaining lower separations than would be the case if the controller maintained responsibility.

5.4.12.4 The use of airborne spacing is also a promising technique for departures. The concept of operations is not as clear as is the case for the approach but is likely to involve maintaining time based separation with the preceding aircraft. One issue here is that there are generally a small number of standard departure routes from airports and establishing separation on each of these routes places an overall limitation on departure rate. The use of RNAV techniques to increase the number of departure routes available in combination with departure spacing offers great potential to increase overall departure rates.

5.4.12.5 On the airport surface, provision of airborne data is expected to increase the pilot's situational awareness and lead to more efficient execution of taxi clearances. JAFTI [115] claim that a key capacity advantage will be enabled by allowing aircraft to operate at smaller separations. In particular, maintenance of closer separations during conditions of poor visibility is seen as a key benefit.

5.4.12.6 In parallel with these developments, provision of an improved situation picture to ground controllers will assist in the provision of more efficient clearances.

5.4.12.7 Table 5-15 shows the ATM applications required to support enhanced capacity in the terminal, approach, departure and airport regions.

#	ATM application	Timescale (intro. – wide usage)	terminal	Airport capacity
APP1a	Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller	2004 – 2005	y	
APP1b	Enhanced surveillance in terminal and en-route airspace providing a w ider range of DAPs	2005 – 2007	y	
APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace	2005 – 2007	y	
APP2b	Strategic controller/pilot messages	2002 – 2004	y	y
APP2c	Support for increased automation	2008 – 2010	y	y
APP2d	Trajectory negotiation	2009 – 2012	y	
APP3c	Enhanced visual approaches	2005 – 2006	y	
APP4b	Provision of full range of uplink information services	2009 – 2010	y	
APP9a	Airborne spacing in en-route and terminal airspace	2006 – 2009	y	
APP9c	Final approach spacing	2005 – 2007	y	
APP9d	Departure spacing	2006 – 2009	y	y
APP10c	Final approach separation	2011 - 2015	y	
APP12c	Enhanced IMC airport surface operations	2007 – 2009		y
APP13a	Fusion of current terminal and/or surface radar w ith alternative surveillance means	2007 – 2009		y
APP13c	Routing	2008 – 2010		y

Table 5-15: ATM applications to support enhanced capacity in terminal and airport regions

5.4.12.8 The impact of these measures is to converge on the maximum arrival and departure rates for airports. Hence capacity becomes limited by the number of available runways.

5.4.13 Safety

5.4.13.1 Section 5.2.3 described the main causes of accident and incident rates in aviation:

- a significant proportion of accidents and incidents might be prevented by enhanced situational awareness. This includes the 18% of accidents attributed to poor situational awareness in the air and the significant proportion of incidents caused by runway incursion. It is clear that provision of ATSAW ATM applications could contribute significantly to a reduction in the accident and incident rate.

- aircraft deviation from ATM clearance is also a significant cause of safety related incidents. Many of these arise because of a mis-understanding by the pilot of the controller instruction. Clearly, use of data link can remove some of these misunderstandings.
- many accidents and incidents arise from inappropriate action and poor judgement. The reasons for this can only be fully understood in the context of each particular scenario. However, it is likely that a) improved situational awareness, and b) enhanced ground monitoring tools, could provide an improved safety net which might prevent such incidents occurring in the future.

5.4.13.2 Provision of improved controller pilot communication and improved ground monitoring are additional safety benefits associated with ATM concepts introduced primarily to provide additional capacity. ATSAW ATM applications generally provide safety benefits only but such benefits are seen as significant and able to justify their implementation. Table 5-16 shows the ATSAW ATM applications which provide enhanced safety.

#	ATM application	Timescale (intro. – wide usage)	Airport safety	Terminal safety	En-route safety
APP1a	Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller	2004 – 2005		y	y
APP1b	Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs	2005 – 2007			y
APP3a	Enhanced visual acquisition (EVA) in remote and oceanic airspace	2007 – 2008			y
APP3b	Enhanced visual acquisition (EVA) in terminal airspace	2005 – 2006		y	
APP3c	Enhanced visual approaches	2005 – 2006	y		
APP3d	Traffic situational awareness in core and transitional en-route airspace	2007 – 2008			y
APP12a	Surface enhanced visual acquisition	2006 – 2007	y		
APP12b	Runway and final approach occupancy awareness	2006 – 2007	y	y	

Table 5-16: ATM Applications to support enhanced safety

5.4.14 Other ATM applications

5.4.14.1 Table 5-17 shows the ATM applications which:

- provide enhanced capacity and flight efficiency in the oceanic and remote regions

- may provide alternative lower cost means of providing ATM infrastructure, and whose adoption should be assessed on a case by case basis.

#	ATM application	Timescale (intro. – wide usage)	Remote and Oceanic	Cost effecitveness
APP1d	Fusion of current radar and ADS-B surveillance in terminal and en-route airspace	2008 – 2010		y
APP1e	ATC surveillance using ADS-B in terminal and en-route airspace	2011 – 2015		y
APP10a	Airborne separation in oceanic and remote airspace	2008 – 2010	y	
APP13b	ATC surveillance using ADS-B at airports.	2010 – 2013		y
APP14a	Basic surveillance infrastructure via ADS-B in remote regions	2008 – 2010	y	
APP14b	ATS in oceanic/remote areas	2004 – 2004	y	

Table 5-17: ATM applications to support operations in remote and oceanic regions and ATM applications to provide cost effective alternatives to current technology

5.5 Summary

5.5.1 The current control paradigm can be optimised to provide an increase in capacity. This capacity will be sufficient for many en-route sectors in Europe. Further capacity increases could be obtained by optimising and segregating traffic flows and this may provide one means of satisfying the operation requirement to provide flexibility is to accommodate user preferred trajectories and flexible planning.

5.5.2 However, regardless of whether traffic flow is optimised/segregated, the results of this section indicate that the basic control task of monitoring and resolving conflicts in en-route airspace is best done by the pilot because the number of conflicts that a controller has to deal with increases as the square of the traffic flow and the only way of controlling this is to reduce the size of the sector. Hence delegation to pilot has great potential to either provide more capacity or to reduce the number of sectors required. Indirect benefit of such “reverse” trend would be slowing-down the rate of new ATC frequency allocations which would otherwise run-out within the addressed time frame.

5.5.3 Note also that to achieve higher levels of capacity with sectorised control means that very careful trajectory planning will be required to avoid conflicts. This in turn reduces flexibility. The results of this section suggest that, rather than impose such a structured planning process, it is better to allow the pilot to resolve conflicts – it is a faster win.

5.5.4 However, the effectiveness of the control process is lowered if:

- the number of conflicts exceeds the capacity of the controller or pilot to deal with them
- the number of aircraft involved in a conflict is more than 2 (or that there is likely to be a knock on effect on other aircraft)[10]

5.5.5 The analysis suggests that a pilot centred approach is feasible in core and remote en-route and remote terminal regions but that core terminal is likely to become too dense.

5.5.6 In en-route regions, the role of ground planning is to manage densities to reasonable levels (light touch planning) through the use of ground holding and the assignment of arrival times and fixes for entry into terminal regions.

5.5.7 The terminal region is characterised by high density but highly systemised flows and it is expected that:

- there will firm imposition of arrival times for inbound en-route aircraft
- aircraft will use advanced navigation systems to fly planned and separated trajectories;
- the controller's role will be to manage merging and diverging flows assisted by appropriate controller tools;
- the pilot's role will be to maintain spacing in response to controller instructions.

6 Stakeholder opinion

6.1 Introduction

6.1.1 This section contains a summary of comments received from Stakeholders.

6.1.2 Two types of input are summarised in this section:

- Comparison of the results in this document with documented output from other groups considering similar issues. This consists of:
  - the Joint User Requirements Group (JURG) ADS Fast Track Initiative (JAFTI) [115]
  - Eurocontrol: CARE/ASAS Activity 5: proposal for a first package of GS/AS applications
- Comments on the material contained in this document from members of the Peer Review Group. At this stage, the comments have been generated against release 1.A of this current document. Input has been received from:
  - Donie Mooney, General Manager ACD, Irish Aviation Authority (IAA)
  - Yves Sagnier, CENA
  - Eurocontrol
  - AENA
  - International Air Transport Association (IATA).

6.2 Comparison with other assessment work

6.2.1 Joint User Requirements Group (JURG) ADS Fast Track Initiative (JAFTI)

6.2.1.1 The following tables provide a cross reference between ATM applications and the initial applications selected by JAFTI [115].

JAFTI	**Extended Visual Acquisition (EVA)**	
APP3a	Enhanced visual acquisition (EVA) in remote and oceanic airspace	2003-2008
APP3b	Enhanced visual acquisition (EVA) in terminal airspace	2003-2006
APP3c	Enhanced visual approaches	2003-2006
APP12a	Surface enhanced visual acquisition	2004-2007

JAFTI	**Improved Approach Spacing (CDTI Enhanced Flight Rules-CEFR)**	
APP3c	Enhanced visual approaches	2003-2006
APP9c	Final approach spacing	2004-2009
APP10c	Final approach separation	2011-2015

JAFTI	**Approach Spacing – Time Based Separation**	
APP9c	Final approach spacing	2004-2009
APP10c	Final approach separation	2011-2015

JAFTI	**Improved Airport Surface Surveillance and Communications**	
APP1a	Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller	2000-2005
APP1b	Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs	2001-2007
APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace	2002-2007
APP2b	Strategic controller/pilot messages	2000-2004
APP4a	Provision of D-OTIS (ATIS, METAR) and D-RVR.	2004-2007
APP4b	Provision of full range of uplink information services.	2007-2010
APP12b	Runway and final approach occupancy awareness	2004-2007
APP12c	Enhanced IMC airport surface operations	2005-2009

JAFTI	**Support for Improved Medium Term Conflict Detection (MTCD) and Conflict Resolution Advisor (CORA)**	
APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace	2005 – 2007

JAFTI	**En-route Crossing**	
APP9b	Crossing and passing in en route airspace	2006-2009
APP 10a	Airborne separation in oceanic and remote airspace	2008-2010

JAFTI	**Improved tracks (accuracy and update rate)**	
APP1a	Enhanced surveillance in terminal and en-route airspace, limited additional information being displayed to the controller	2004 – 2005
APP1b	Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs	2005 – 2007

JAFTI	**Use of ADS-B for double or triple surveillance coverage**	
APP13a	Fusion of current terminal and/or surface radar with other surveillance means	2004–2009
APP13b	ATC surveillance using ADS-B at airports.	2005-2013
APP14a	Basic surveillance infrastructure via ADS-B in remote regions	2002-2010

6.2.1.2 The following opinion has been received based on [115]:

- OC1: Support for use of ADS-B data to support MTCD and CORA tools. Still considering position on use for double or triple radar coverage and for improving accuracy and update rate of tracks.
- OC3: APP3b supported as it leads to additional landing rates in VMC, enhanced safety and reduced probability of go-arounds. APP3a supported [115] as substantial benefits are expected for visual approaches.
- OC9: Enthusiasm from operators for general operational concept. APP9c has been given full support as a means of supporting capacity in poor visibility and for providing time-based separation on the approach path.
- OC10: Enthusiasm from operators. APP10a is supported as part of "en-route crossing" ATM application but not necessarily part of first package. APP10c final approach separation is supported as part of JAFTI package "improved approach spacing (CDTI enhanced flight rules-CEFR) as a means of increasing airport capacity in poor visibility conditions. It also provides time-based separation on the approach which is claimed to provide substantial benefits at airports like London Heathrow and Gatwick.
- OC11: Enthusiasm from operators.
- OC12: APP12a and APP12b fully supported as part of JAFTI ATM application "improved airport surface surveillance and communications".
- OC13: APP13b fully supported as part of JAFTI ATM application "improved airport surface surveillance and communications" (possible case to accelerate this ATM application).
- OC14: APP14a: Still considering viewpoint on use of ADS-B in remote airspace.

6.2.1.3 It is concluded that JAFTI are promoting early use of ADS-B and that the timescales for many of the proposed applications are directly compatible with those proposed for the equivalent ATM applications defined in this document. Note however that there is a greater emphasis on use of separation:

- to maintain approach rates during poor weather conditions;
- to provide time-based separation on the approach.

This corresponds to earlier implementation of APP10c than is proposed in this document. It is recommended that early implementation of APP10c is considered as a means of introducing, and gaining confidence with, separation related ATM applications in general.

6.2.2 Eurocontrol: CARE/ASAS Activity 5: proposal for a first package of GS/AS applications

6.2.2.1 This section relates the applications considered in ASAS package1 [116] to those in the application assessment document:

6.2.2.2 Note that Package 1 focuses on delivering benefits related to operational improvements (OIs) in periods 2 and 3 of ATM2000+ roadmap. This corresponds to 2005 – 2007 for period 2 and 2008 – 2011 for period 3. It is assumed in this section that the earliest date for realising benefits associated with a Package 1 application is therefore 2005.

6.2.2.3 [116] refers to ground surveillance (GS) and airborne surveillance (AS) applications. Therefore the terms GS applications and AS applications are used to refer to applications defined in [116]. The term "ATM application" refers to applications defined in this document by the study team.

6.2.2.4 Note also that the timescales quoted for GS/AS applications relate to the "lifetime" over which the application is expected to deliver benefit. The timescales provided for ATM applications relate to the transition period from initial implementation to widespread usage. Therefore, in the comparison made below, it is to be expected that the ATM application timescales should correspond to the start of the GS/AS application timescale.

GS	**ATC Surveillance for en-route airspace** (ADS-B-ACC)	2005-2020
APP 1d	Fusion of current radar and ADS-B surveillance in terminal and en-route airspace	2005-2010
Notes	In 2005-2007, it is assumed in Package 1 that this will be used for providing redundancy for basic surveillance coverage. This is consistent with timescales for APP1d.	

GS	**ATC surveillance in terminal areas** (ADS-B-TMA)	2005-2020
APP 1d	Fusion of current radar and ADS-B surveillance in terminal and en-route airspace	2005-2010
Notes	See comments on ADS-B-ACC	

GS	**ATC surveillance in non-radar areas** (ADS-B-NRA)	2008-2020
APP14a	Basic surveillance infrastructure via ADS-B in remote regions	2008-2010
Notes	The Package 1 document relates this application to OI 030403, the provision of airborne data, and hence the service is not required until 2008. However, it seems more appropriate to the provision of basic surveillance services (ie 030404) which is required in periods 1 and 2. The viewpoint taken in the current study is that provision of such a service is immediately desirable but that the implementation is limited by the need to achieve a high ADS-B equipage. The timescales for first implementation are therefore compatible with those assumed in Package 1, albeit for a different reason.	

GS	**Airport Surface surveillance** (ADS-B-APT)	2005-2007
APP13a	Fusion of current terminal and/or surface radar with other surveillance means	2007-2009
APP13b	ATC surveillance using ADS-B at airports	2010-2013
Notes	The package 1 application contributes to OI 040101 through the provision of additional data. The timescale is compatible with APP13a. The package 1 application also is intended to provide basic surveillance at small airports. This corresponds to APP13b which has rather later timescales than is proposed for the package 1 application. The study derived these timescales on the basis of achieving high equipage levels at busy airports. It is possible that a much earlier timescale is possible at small airports with local aircraft fleets.	

GS	**Aircraft derived data for ATC tools** (ADS-B-ADD)	2005-2020
APP1a	Enhanced surveillance in terminal and en-route airspace, limited additional information being displayed to the controller	2004 – 2005
APP1b	Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs	2005 – 2007
APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace	2005 – 2007
Notes	In package 1, the first use of airborne data is foreseen to be in support of enhanced tactical flow and capacity management from 2005. Use for tactical control purposes is not foreseen until 2012. However, airborne data is required in the period 2004 – 2007 to enhance controller tools (APP1a to APP1c). One technical solution for APP1a is Mode S enhanced surveillance. However, if it is intended to consider ADS-B technologies as an alternative, then Package 1 should provide this capability earlier.	

AS	**Enhanced traffic situational awareness on airport surface** (ATSA-SURF)	2005-2007
APP12a	Surface enhanced visual acquisition	2004-2007
APP12b	Runway and final approach occupancy awareness	2004-2007
APP12c	Enhanced IMC airport surface operations	2005-2009
Notes	GS/AS Application timescales compatible with ATM applications.	

AS	**Enhanced traffic situational awareness during flight ops** (ATSA-AIRB)	2008-2020
APP3a	Enhanced visual acquisition (EVA) in remote and oceanic airspace	2007-2008
APP3b	Enhanced visual acquisition (EVA) in terminal airspace	2005-2006
APP3d	Traffic situational awareness in core and transitional en-route airspace	2007-2008
Notes	ATM applications introduced slightly earlier than GS/AS applications.	

AS	**Enhanced visual acquisition for see & avoid** (ATSA-S&A)	2008-2020
APP3a	Enhanced visual acquisition (EVA) in remote and oceanic airspace	2007-2008
Notes	ATM application timescale compatible with GS/AS application.	

AS	**Enhanced successive visual approach** (ATSA-SVA)	2005-2020
APP 3c	Enhanced visual approaches	2003-2006
APP 9c	Final approach spacing	2005- 2007
Notes	ATM application timescales for spacing compatible with GS/AS application.	

AS	**Enhanced sequencing and merging operations** (ASPA-S&M)	2005-2020
APP 9a	Airborne spacing in en-route and terminal airspace	2006-2009
APP 9b	Crossing and passing in en-route airspace	2006-2009
Notes	In [116] this AS application meets a number of OIs in different timescales. The early implementation appears to focus on terminal operations (010403) which is in line with the equivalent terminal ATM applications. Early en-route OIs relate to sector optimisation (010501) and general traffic situational awareness (040102). It is unclear whether it is the intention to implement, for example, airborne spacing in en-route airspace although the implication is that this will not deliver benefit until period 4 (2012 – 2020). The benefit analysis has concluded that spacing in en-route airspace is an important step towards separation and self-separation and delivers additional capacity in its own right. Therefore, it is recommended that there is an earlier implementation than that implied in [116].	

AS	**In-trail procedure in oceanic airspace** (ASPA-ITP)	2012-2020
APP 10a	Airborne separation in oceanic and remote airspace	2008-2010
Notes	This study indicates that the ATM application is required earlier than 2012. Note that [116] indicates that this GS/AS application could be implemented earlier and act as a “bridge” between package 1 and package 2.	

6.2.2.5 In general, the timescales proposed for delivery of benefits from GS/AS applications in [116] are compatible with the timescales proposed for introduction of the equivalent ATM applications described in this document. The following variations arise:

- the timescales for provision of basic surveillance data via ADS-B are earlier in GS application ADS-B-APT than is proposed for the equivalent ATM application APP13b. The current study has derived the timescales for APP13b on the basis of achieving high equipage at medium to large airports. It is possible that a much earlier timescale is possible at small airports with local aircraft fleets. Note also that JAFTI [115] promotes the early adoption of this ATM application.
- GS application ADS-B-ADD covers provision of airborne data for enhanced tactical flow and capacity management from 2005. Use of such data is not foreseen in [116] until 2012. However, the results of the application assessment indicate that airborne data is required in the period 2004 – 2007 to enhance controller tools (APP1a to APP1c) so as to provide additional capacity. Although one technical solution for these applications is to use Mode S enhanced surveillance, an alternative is to derive such data from ADS-B technology. Hence, if the ADS-B approach is taken, ADS-B-ADD for tactical airborne data would be required earlier. The Community needs to decide if it is better to extend to Mode S mandate to cover enhanced surveillance applications or whether it is better to invest in widespread adoption of ADS-B technology.
- In [116] the AS application ASPA-S&M meets a number of OIs in different timescales. The early implementation appears to focus on terminal operations (010403) which is in line with the equivalent terminal ATM

applications. Early en-route OIs relate to sector optimisation (010501) and general traffic situational awareness (040102). It is unclear whether it is the intention to implement, for example, airborne spacing in en-route airspace although the implication is that this will not deliver benefit until period 4 (2012 – 2020). The benefit analysis has concluded that spacing in en-route airspace is an important step towards separation and self-separation and delivers additional capacity in its own right. Therefore, it is recommended that there is an earlier implementation than that implied in [116].

- The application assessment has indicated that APP10a (airborne separation in oceanic and remote airspace) is required earlier that the equivalent AS application ASPA-ITP (in-trail procedure in oceanic airspace). APP10a provides efficiency benefits and acts as an early opportunity to implement airborne separation. As such, it is an important enabler for later ATM applications based on separation.

6.2.2.6 Broadly, the results of the application assessment support the emerging package 1 proposal. The main concern relates to the implementation of ATM applications based on spacing, separation and self-separation. The benefit analysis has concluded that provision of sufficient capacity in the longer term relies on widespread adoption of spacing, separation and self-separation. In particular, spacing provides a useful addition to capacity in the period to 2011 whilst separation will need to become an important provider of capacity in the period 2011 –2015. Currently, separation in en-route and transition areas is not foreseen until Package 2, which is not provided with a firm timescale in [116]. Therefore, it is essential that the community plans a transition towards separation during the period of package 1. At the least, this should include operations involving en-route spacing and pre-operational trials of ATM applications related to separation. Early community activity related to separation ATM applications should focus on:

- oceanic and remote regions (APP10a);
- approach separation (APP10c) in line with recommendations by JAFTI ([115]).

It is recommended that firm timescales are agreed at a Community level for implementation of ATM applications based on en-route spacing and separation in order that appropriate development actions can be taken in parallel with Package 1 implementation actions.

6.3 Comments received from Peer Review Group

6.3.1 Overview

6.3.1.1 A large number of comments have been received from the Peer Review Group. These have generally expressed support for the work and the conclusions drawn. Where comments were editorial or simple to address, modifications have been made to the document. There are a number of areas where further clarification and analysis was required. These are summarised below together with the action taken:

- ISSUE 1: There is a need for more emphasis and analysis of collaborative decision making. Response: this is viewed by the study team as a driver for ground-ground communication, supported by data provided by other ATM applications analysed during the study.

- ISSUE 2: APP2b: Strategic controller/pilot messages: benefits underestimated and this ATM application should be given higher priority. Response: The priority has been increased for this ATM application.

- ISSUE 3: OC9/10/11: views vary

  - underestimation of benefits: eg capacity benefits in oceanic

  - benefits still need to be proven

  Response: Because of the varying views, enumeration of the benefits is left as a future action for the Community.

- ISSUE 4: OC3

  - ATSAW not seen as an ATM application

  Response: disagree because of the high support for EVA shown by other stakeholders.

- ISSUE 5: OC13

  - further analysis of airport benefits required

  Response: no further action has been taken.

- ISSUE 6: Meaning of timescales. It is not clear what is meant by the timescales presented in the document. It was agreed at the Stakeholder workshop that an additional timescale would be added corresponding to when an application might be first introduced as part of an early implementation. This will be added during Phase 2 when more information on the underlying technology has been obtained. Response: clarification added to report.

- ISSUE 7: Dependence of timescales on region of application. It is recognised that timescales and the content of the ATM Application roadmap may vary according to the density of the airspace in which the ATM Application is applied. Information on this will be gathered during Phase 2 and incorporated into the document. Response: addressed during Phase 2.

- ISSUE 8: Views on timescales vary.

  - optimistic because eg safety cases can take longer. The delay is greater if mandation is required

  - pessimistic in particular, OC9/10/11/13/14 should be achieved earlierThe conclusion of the workshop was that, in general, the timescales are achievable given an industry-wide commitment to them. The purpose of Phase 2 is to assess if the commitment is possible given the realities of technology availability. Response: modification to timescales analysed in Phase 2.

- ISSUE 9: Greater emphasis should be given to 4D trajectory negotiation. Response: Addressed in Phase 2 as Step 5b of the roadmap.

- ISSUE 10: Not enough emphasis is given to introduction of spacing/separation/self-separation ATM applications. Response: Addressed in Phase 2 as Step 5a of the roadmap and in general through the early implementation of spacing.
- ISSUE 11: Correlation with developments outside Europe should be included. Response: addressed in Phase 2 as a criteria for data link technology selection.
- ISSUE 12: There is a need to validate the benefit calculations presented in section 5 particularly in respect of the benefits associated with delegation to pilots. Response: validation outside scope of the current study – left as a future Community action.
- ISSUE 13: There needs to be a greater emphasis on security services. Response: Outside the scope of the study.

6.3.1.2 Other specific responses are included in the following sections.

6.3.2 Eurocontrol

Paragraph Number (version 1.A)	Comment	Action
General	A much improved document with lots of interesting material	No Action required
General	The level of the Ocs seems uneven, for example ATSAW gets a whole OC but has a minimal change to ATC , whereas Trajectory Negotiation, a revolution that will require a change of all FMSs, FDPs, communication infrastructures and procedures it is just hidden inside OC2.	Agreed but we have tried to provide a top down structure and, in places, this has made the OCs uneven. At this stage, no further action is proposed.
1.1.2	I would be worthwhile to explain the European decision-making process which is envisaged and how it fit with the current Aviation decision decision-making process. This point is very important to understand the total study process. This is an essential point should be presented and discussed at the workshop introduction	Agreed. This will be addressed during the “community actions” part of Phase 2. ACTION – not yet addressed
Figure 2-3	Did not print out	Re-pasted
3.	Suggest add a summary table (for readability) at the beginning of section with all ATM applications and OCs	Implemented
3.1.1	It should also be clearly identified that the ATM application choice shall at least be interoperable with choice in other regions	Clarification added.
3.1.2	Clarify what ‘cost effectiveness’ means. Is the implication that (for high) costs will go down for the ANSP? Airlines? Passengers? How is this linked to ‘ impact on infrastructure in § 4? E.g APP2a/b/c/d cost-effectiveness (None), Impact on ground and air infrastructure is 3 or 4.	Explanatory paragraph added under table 3-1.
3.1.2	Is it meaningful to assess two criteria which are, from my point of view, and considering the level of uncertainty of the assessment, closely related e.g. “Flight efficiency” and “Environmental impact”. Flight efficiency should be enough	Agreed. The environmental impact has been maintained in Section 3, but the detailed benefit analysis considers just flight efficiency.

Paragraph Number (version 1.A)	Comment	Action
3.2.2.4	I suggest withdrawing "being made for initial implementation of Mode S ... and may be more appropriate in some airspaces". This is somehow already introducing early conclusion on technology	Implemented
3.2.2 table section capacity	what is the relation ship between these applications and the wake vortex?	Clarification has been added
§ 3.2.3.3. 2nd bullet	In Europe PDC is DCL	Implemented
§ 3.3.5.4 3rd line	which are <u>not</u> solved	Implemented
§ 3.4	No convincing argument APP11a will deliver large benefits	Believe that the benefits arise through substantial reduction in controller monitoring workload. Note added and cross reference to section 5.
§ 3.4.2.4 4th bullet (as well as 3.4.3.4, 3.4.4.4)	Based on the current specifications, could you explain/justify the aircraft to aircraft point to point data link need?	This is based on a feeling that if two aircraft are manoeuvring relative to each other, there will be a need to confirm from one to the other that they are aware of each other. Considered further during Phase 2 and left as an action for the Community to assess the need for this service.
§3.5.3	No convincing argument that APP13a brings any benefits.	Agreed that benefits only occur through providing an alternative technology to eg multi-lateration.
§ 4	It is assumed that the Timescales (for package 1 applications) are consistent with those from CARE-ASAS and JAFTI . Please confirm this	A cross reference section has been added to the document to compare timescales. Differences have been highlighted
§ 4.2 tables estimated timeframe & critical path elements	The critical path estimations will need to be carefully reviewed by the concerned aviation actors since these figures are context dependant. From my side, I have not yet fully reviewed all the figures	Agreed
§ 3.5.3	Suggest either add mutli-lateration as an enabler in 13a/13b or add additional OCS for multi-lateration.	Potential role of multi-lateration already highlighted in 3.5.3.3

Paragraph Number (version 1.A)	Comment	Action
§ 7	Please clarify 'widespread operational use'. Does it relate to equipage or geographical region?	It means achieving a level of equipage in a sufficiently wide geographic region to deliver the claimed benefits.
§ 7	It may not be possible to implement some of the applications in central Europe in the timescales suggested (e.g APP9c by 2007). Suggest add two timescale columns, one for low/medium traffic density, another for high density. Is this division helpful for the benefits identified in § 3?	See Issues 6 and 7
7.2.2.6	If possible indicate who has to make the key decision	Addressed in Phase 2
7.2.2.6	If possible which are the 'show stoppers' and demand immediate attention.	Addressed in Phase 2

6.3.3 CENA

Paragraph No. version 1A	Comment	Action
General	Content : good general impression, well structured document, being based correctly on the existing documentation (Po-asas and COOPATS in particular), but with a good analysis (not a direct paste & copy). However, the references are mainly European and ICAO does not seem to appear.	For information only
General	I suggest to study (roughly) the report of the first meeting of ICAO's ATMCP (ATM Concept Panel) in which effort has been made in order to clarify the vocabulary related to ATM, and add this as a reference.	Review carried out
General	A general presentation of the purpose of the whole contract should be put at the beginning of the document, indicating the different phases and their schedule, and the fact that phase 1 deals with application survey and phase 2 with technological issues (all this appears but in different paragraphes not directly connected). Not a critical issue !	A separate document has been provided on this
2.3.2	In para 2.3.2, the drawing "Top down process for identifying ATM applications" must be understood as a *mere example* about the way to proceed in order to define the ATM applications. As it is, one may understand that the only applications dealt with are related to delegation of control to the aircraft.	Clarification added
Issue 1: Is the list of ATM applications complete? What other ATM applications should we be including in the study?	I think that applications relating to ensuring the real-time *consistency between trajectory/flight plan information between the ground and air* systems are missing. Such an application has been selected inside Link2000+, named Flipcy, but it has been defined some years ago and would not fit exactly the problems of the situation. This consistency application should use partly ground-ground exchanges (as part of CDM), and partly air-ground data-link (like Flipcy). Eurocontrol made a study indicating that such inconsistencies are numerous today but have little operational impact. However, they should be reduced through a combination of actions. This also has an impact on the benefits expected for Dynav (OC7)	We have taken the view that this application delivers little benefit in its own right but is a constituent enabler for other ATM applications. As such it is included in the derivation of technical requirements

Paragraph No. version 1A	Comment	Action
Issue 2: Have we identified all the relevant benefits for each ATM application? Is there anything missing? Have we overstated or understated the likely scale of benefit?	About ASAS applications (OC3, OC9, OC10, OC11): page 13 description of the benefit : one must pay attention not to have a purely ground based vision : in the expected benefits, the gains in capacity are done by evaluating the reduction in the controller workload without speaking about the pilot workload; the benefit in safety are related to the incidents and one knows that it is always reducing. In the two summary sheets on spacing, page 28, and separation, page 30, the profits in capacity are said to be similar and to be really higher only when airborne minima are smaller than minima ATC. In fact, CENA current project ECLECTIC aims at showing that the profits in safety and capacity will exist *even if the airborne minima value is higher than that of the ATC*. The delegation of responsibility for conflict detection and resolution to the air-crew will produce gain in capacity and safety since the controller will be able to better manage the remainder of the traffic.	Note added to OC11 and OC12
	OC7 (Dynamic route Availability) : I would not use this title as it refers to a specific Data-Link service defined by ODIAC (DYNAV), which would not be as useful as expected if implemented as such. We made a study in France indicating that already today the best routes are proposed to the pilot as soon as a military zone is deactivated for instance. Implementing Dynav would not give benefits. Moreover, it would require first to ensure the consistency between the air and ground trajectory information (see here above about Flipcy). The aim to keep is to give a "user preferred route" in a general way, and through different processes, with different scales of time ahead. I think OC7 should be retitled as such and would include Dynav if you want to keep this specific service, but also other ones : Dynav is limited to the allocation of predefined routes when they become available, whereas "user preferred routes" can comprehend other schemes (some of them being to define by the way).	Agreed that title is misleading – however decision taken not to change to maintain consistency throughout project.
	OC14 (ATS in oceanic/remote areas) : As these applications are expected to be based solely upon ADS-B on this study, the dates are rather far in the future. Today, ATS services are already given in such areas through ADS-C (that is ADS but not broadcast, using FANS 1/A). See ATC Market report Volume 11, No7 (April the 4th, 2002), pages 7-8.	Comment added to table for OC14. Dates reviewed in Phase 2
Issue 3: Are the timescales estimated for the ATM applications realistic? If not, what are the main reasons for changing the expected timescale?	For OC4/D-OTIS : this service is already available in some areas : ATID is already input as text and broadcast both by vocal link (through automatic reading) and data-link (through ACARS/FANS 1 today, VDL2/ATN later). The timescales relative to ASAS (OC3, OC10) are coherent with those announced in the European projects (review of ASAS applications in Europe).	Comment on OC4 added to table. Timescales for APP4a modified

Paragraph No. version 1A	Comment	Action
Issue 4: Which ATM applications do you believe offer most benefit and are likely to gain the most active support of your organisation? Conversely, which ATM applications would your organisation not support and why?	I can only say that we are committed inside Link2000+ and are working very actively on ASAS experiments.	For information only

6.3.4 IATA

6.3.4.1 The following opinion has been received based on input from study team members:

Paragraph No. version 1A	Comment	Action
OC1: APP1a/b:	Expectation of the results of current research are low (eg real time simulations are needed to prove that use of heading to monitor parallel approaches will deliver more benefits). Therefore currently unenthusiastic about this operational concept (worried that this should not become part of mainstream and not convinced by 5% benefit claims).	For information only
OC2:	Supported and feel it is needed now	For information only
OC12:	Enthusiasm from operators but balance between costs and benefits needs to be assessed.	For information only
OC13:	A-SMGCS routing will involve acquisition of new equipment for aircraft as well as ground. This implies extra costs, which need to be balanced with expected benefits. Enthusiasm from operators but balance between costs and benefits needs to be assessed.	For information only
OC14:	APP14b generally supported by long-range operators.	For information only

6.3.5 AENA

Paragraph Number (version 1.A)	Comment	Action

Paragraph Number (version 1.A)	Comment	Action
3.2.2	Benefits for OC1, APP1e: The application talks about using ADS-B technology "alone" in terminal and en-route airspace. We do not see feasible to have only ADS-B in terminal areas (at least in high density areas you will always have a radar)	Agreed a further note has been added to the table for OC1
3.2.4	Benefits for OC3, ATSAW, APP3b and APP3b: The benefits linked to capacity increase are not clear to us. The core idea of ATSAW is the knowledge of where the other aircraft are. The idea of reducing the separation comes from using the information obtained through ADS-B (or other means) to change the separation. But if you change the separation you are doing some different (more like OC9, OC10). At least from my point of view the benefits come from safety side (and may be efficiency), as you have already identified.	The capacity claim results from JAFTI's belief that operations under VMC are not optimum. The use of ATSAW will help apply VMC procedures more efficiently
3.2.5	Benefits for OC4: The table of benefits talks about increased safety by the cells in the table are marked as benefits "none". Should it be "small"?	Implemented
3.4.2.4	Benefits for OC9 (spacing): Some people think that it could bring some flight efficiency benefits in final approach.	Implemented
4.2.1	Times scales for OC1: The dates seem too pesimistic, but difficult to say specific dates.	Noted – no change made at this stage
*- Section 7.2.3.- Widespread ops status by the end of 2015	Table 7-6 seems pesimistic for APP13b (ATC surveillance using ADS-B at airports	This point raised by several stakeholders – timescales will be revised See issue 8
*-Section 7.2.3.- Widespread ops status by the end of 2015	Table 7-7.-APP1e (surveillance using ADS-B "alone" in terminal areas). We have the same comment as above (We do not see feasible to have only ADS-B in terminal areas (at least in high density areas you will always have a radar)	Note raised on table
*- Comment on references:	In the references, please consider that there is a new version of the JAFTI document (the last one is from May 2002, version 1.2)	Implemented

6.3.6 IAA

Paragraph No. version 1A	Comment	Action
List of applications	In relation to the list of applications I believe that the list is comprehensive enough and if all the applications meet the operational milestones the ATM paradigm will be significantly different from the current system.	No action required

Paragraph No. version 1A	Comment	Action
Benefits of ATM Applications	In relation to the Benefits of the applications, please note: The Cost Effectiveness of applications APP1a, APP1b and APP1c are listed as small (see page 16). The Cost Effectiveness of APP2a, APP2b, APP2c and APP2d are listed as having no cost benefit identified (Page 19). APP3a, APP3b, APP3c and APP3d are listed as having no cost benefits identified (Page 21). APP4a, APP4b, are listed as having no cost benefit identified (Page 23). APP7a is listed as having no cost benefit identified (Page 25). APP9a, APP9b, APP9c and APP9d are listed as having no cost identified (Page 28). APP12a, APP12b and APP12c are listed as having no cost benefit but may provide alternative surveillance infrastructure at small airports. For non ATM involved people who may read the report (accountants), an eyebrow may be raised at such a long list of applications without a tangible cost benefit. I think we are understating the benefits somewhat, but I accept that quantifying the benefits is not easy.	Section 5 addresses this issue
Timescales	The timescales indicated in this document are, by and large, realistic but I would not underestimate the potential for certification and validation issues to impose delays. I also believe that the timescales will only be met if the introduction of such a range of applications are part of a European project i.e. the introduction of RVSM in Europe.	Noted
Irish Aviation Authority preference (IAA)	At the moment the major project been undertaken by the IAA is the ATM Upgrade Project with a new Centre in Shannon, a move to an extended building at Dublin and a new Tower Building in Cork. It is expected that the new system will be fully operational in 2004. Any new enhancements of the system such as the introduction of datalink applications will not be contemplated until 2004. Thereafter, depending on the complexity of the work associated with an upgrade, we are looking at approximately 2 years from the stated requirement to the operation of the Application. It is important to bear in mind that the IAA does not have a R+D department so the Policy & Systems arm of our organisation must have an Operational Requirement in order to proceed with any work. To date no requirement has been mooted from the Operations area for data link. By and large the IAA will implement developments as they mature through the EATMP process. Some discussion has taken place between Dublin Operations and Policy & Systems on ASMGCS but these discussions fall far short of a stated Operational Requirement.	Noted for information

Paragraph No. version 1A	Comment	Action
General Comment	The issue of a Mandate for the introduction of a wide spread use of data link is an important one. The question is 'who is driving the data link issues' ? If there is not a clear answer to that question, the introduction of datalink on the scale proposed will not happen in an organised fashion, some Organisations will provide Datalink services and possibly their neighbours being years away from providing the same service. The IAA has a very effective Customer Care programme in place and to date the airlines have not indicated that the introduction of datalink is one of their priorities. If pressure for datalink does not come from the airlines I believe the timescales indicated will not be met. It is also important to remember that the introduction of Mode S Elementary Surveillance in the core European Area, if indications are correct, will not happen until 2005/2006. In my view without a mandate, development of DAPs will not be a priority until after Elementary Mode S introduction. The mode S issue may delay the wide spread introduction of Data Link Applications	Presented for information
Specific Items	For the Applications APP 11a and APP 11b (Page 32) and indeed APP 10a, APP 10b and APP 10c (Page 30) I do not agree that we should state that the cockpit workload of aircrew will decrease because of those applications. In fact I would suggest that, human nature being what it is, that as aircrew become more responsible for their own separation that the workload will actually increase (concentration, evaluation, corrective action etc).	Agreed and an amendment made to the tables

Paragraph No. version 1C	Comment	Action
Chapter 5	In broad terms I agree with the Benefit Analysis outlined in Chapter 5. The detail in relation to costs generated by User charges, delays and inefficient routeing was thorough and the impact of introducing data link applications on their reduction was effective. However, I note that in paragraph 5.4.6.9 the document states that taking the combined measures of improved downlink data, automation of communications and conflict probe, the increase in capacity will be 45%. This increase draws on fairly large assumptions namely that controller workload will decrease by the order of 25%(monitoring), 50%(communications) and 50%(conflict probe). These assumptions would need further study and some form of validation to ensure that a 45% increase in capacity can be claimed. Similarly the assumptions underpinning the claimed capacity increase for conflict free trajectories (conflict resolution workload reduction 90%)needs corresponding validation and/or study.	See Issue 12
General	The delegation of control responsibility to pilots is unchartered territory and although the issue is effectively explored (paragraphs 5.4.9 to 5.4.11.5.) I suggest that statements of capacity increase as a result of data link applications in support of delegation of control tasks to pilots should be made with extreme caution.	Issue 12
General	There will undoubtedly be capacity increases but the stated level of increase should err on the cautious side. I believe that because of the evolutionary nature of these concepts that the statement made in the Summary (paragraph 5.5.2) is too strong.	Issue 12
General	I have no difficulty with the selection of ATM Applications or with the prioritisation of same.	Noted
Page 13	Figure 2-3 is blank.	Amended
Page 66	5.2.3.13 – insert "thereby" for "so as".	Done
Page 74	5.3.11 – insert "with".	Done

Paragraph No. version 1C	Comment	Action
Page 77	5.4.2.10 – change “to” to “or”. 5.4.3.1 – change “wold” to “would	Done

6.3.7 MITRE

Paragraph No. version 1A	Comment	Action
General	We particularly like and agree with the summary of benefits and ratings.	Noted
General	There is little/no emphasis on communication with Airline Operations Centers (AOCs) which is of growing importance in the U.S. in this timeframe, but perhaps not as important in Europe.	Issue 11
General	There could be more emphasis on security services provided by communications, and also more emphasis on integration of communication systems/services with FMS capabilities, in the OC2 area of enhanced communication efficiency.	Issue 13
Section 4	Section 4 is very interesting and we are in general agreement with the constraints and critical path elements. We feel that the timescales are optimistic/ambitious, however. (Certainly more time is needed to carefully review this section, but I am wondering if this should wait until the next version of the document...?)	Issue 8
Some more specific comments	When discussing progressive delegation of responsiblity to the pilot (p. 9, and in OC9 p. 26-27), you could add "merging" applications along with spacing applications. There is some very good work being done in EEC and at MITRE related to delegation of merging in particular during approach phase of flight. Also on p. 26 in the description of the operational context, you say that the pilots in addition to the "airborne elements" take increasing responsibility for decisions. You could also allude to the continued need for traffic management into and out of FR airspace or operations. This is a major challenge of this application.	Clarification added
p14	Regarding provision of information from the aircraft (p. 14), perhaps you could add wind information which would be of high benefit in particular for wake avoidance and reduced wake separation applications.	Added as indicated
p14, p15, p27	The use of the terms "downlink broadcast" (e.g., p. 14), "aircraft to ground broadcast" (p. 15), "ground to aircraft broadcast" and "aircraft to aircraft broadcast" (p. 27) is not consistent with terminology we typically use in the U.S. Normally, "broadcast" offers information to any other user including the ground and isn't addressed specifically to the ground.	Cross reference added
p16	In the summary of benefits for App1a to App1c, surface management could be added to the list of other benefits enabled (p. 16).	Clarification added
p22	It is not clear how COTRAC is involved in APP4B (p. 22). Could this be explained?	Clarification added
OC8	In OC8: Free Route (p. 26), you could add ETAs and RTAs in addition to "waypoints" in 3.3.5.3.	Added as suggested
P28	P. 28, need to define what is meant by "ground allowed separations". This is unclear.	Added as suggested
P33	P. 33, you could add "to AOCs" at the end of the first bullet under 3.5.1.2. Also on p. 33, you refer to VFR as "visual flying rules", but in the U.S. it stands for "visual flight rules".	Check made and the correct form added
Section 3.5.3	Section 3.5.3 on p. 35 refers to A-SMGCS but does not really address it (in particular guidance). More description could be added on A-MGCS.	More detail added

Paragraph No. version 1A	Comment	Action
Section 6	Stakeholder opinion, under JAFTI, it is not clear how ADS-B provides a 20-minute look ahead.	Depends on the technology used – addressed in Phase 2
Section 7	The first bullet in 7.1.4 referring to applications achieving widespread operational status by end of 2006 would in most cases refer to existing funded programs and equipage plans, correct? If funded programs are not in place and equipage plans do not exist, it would be difficult to achieve widespread status in our opinion. The timescales appearing in this section we also feel are optimistic (e.g. Section 7.2.2.1 and 7.2.2.2).	Clarification added Issues 6 and 7
P61	On p. 61, it is unclear what is meant by "supported by extension of a current technology" in the last sentence. Does this refer to FANS?	Yes it refers to FANS1/A

6.3.8 ARINC

Paragraph No. version 1C	Comment	Action
General	How will the role of existing equipage be captured in the study? Specifically, if airspace users have already equipped for /using AOC data link communications (e.g., ACARS, VDL M2). Existing equipage has a significant impact on cost/risk assessment. Study doesn't seem to adequately address the risks (schedule, political) for applications that need 100% equipage and/or mandate. These items are noted, but are rated relatively low risk. This is contrary to what I've seen within the CPDLC programs – and that is a relatively straight forward program (no new operational concept – just an extension of use of data link for communications, which the industry has had a number of years experience in already). For example, whether or not a mandate is required has been ongoing for 2+ years; and if/when a mandate is made, IATA has indicated a 7 year lead time. Meanwhile while the debates are ongoing, most of the stakeholders don't commit funds and/or seriously start implementation planning - which contributes to overall implementation schedule slip. Study also doesn't seem to adequately address the schedule risks associated with the imfamous "chicken and egg" problem endemic within the community for non-mandated programs.	Issue 8
Section 2.2	Benefits and implementation constraints analysis are not enough. Full application costs (technical, schedule, risk) must be taken into account in order to take a true accounting for implementation recommendations. The data link infrastructure portion of the system could in fact be one of the least costly portions of the implementation.	Phase 2 assessed these aspects
Section 3.2.2	Some weather information is already being downlinked today from aircraft and used in order to improve current and near term weather information/ situational awareness. Is there an ATM application id'd for this, or is it considered an sub-application to something else, or not applicable?	It is a sub-application – clarification added
OC2	APP2b capacity should be medium or large. Based on L2k+ biz plan simulation 50% equipage -> 8% capacity/75% equipage ->11% capacity increase. Also reference European C/AFT; US C/AFT; FAA simulations (en-route and terminal); FFSC CBA. In addition, use of data link is envisioned to reduce the pressures of increasing resectorization to address R/T congestion problems. "Frequency congestion is the limiting factor in sector operations and [CPDLC] will allow controllers to work significantly more traffic within a sector. " – Ruth Marlin, Executive VP, NATCA	Issue 2
OC2	APP2b safety may warrant a medium rating. For example, in the US in 1998 there were 885 operational errors of which 28% were directly attributed to communications; 1999 saw 940 operational errors, 27% attributed to communications. CPDLC is expected to significantly reduce comms errors.	Issue 2

Paragraph No. version 1C	Comment	Action
OC2	APP2b flight efficiency should be small to medium. Reference US and European studies above which shows significant operations delays and more efficient routing enabled through use of CPDLC. (for example pls see attached slide of TIROE sector) Also, significant improvements in departure planning/ efficiencies are already seen in ACARS-based PDC/DCL.	Issue 2
OC2	Cost effectiveness should not be 'none' – implementing CPDLC on a shared AOC/ATC network enables ANSPs to reduce RF congestion/ reduce need to implement more R/T channels, at the same time as not having to pay the entire costs associated with a data link network. In addition, if a shared AOC/ATC network is used, it also drives down the costs of airline equipage due to common avionics equipment.	Issue 2
OC2	Overall enabler and other benefits may warrant a 'medium' rating – as noted later in the document, CPDLC will a) trail-blaze the certification and implementation/integration issues associated with data link implementations and b) familiarize and improve comfort levels to controllers and pilots in the use of / reliance of data link and increased automation within the operations.	Issue 2
Section 3.2.5.3	Parts of this application (e.g., D-ATIS) are already implemented over ACARS.	Noted and a clarification added
Section 3.2.5.4	Anecdotally, pilots find benefit in point-to-point (long range) availability of D-ATIS data; it is not uncommon for pilots to request weather updates as often as 5 times within a flight.	Clarification added
OC10 (Capacity)	Based on this paragraph, 'medium" doesn't seem to be justified – maybe small or none or TBD.	Reviewed
OC10 (Safety)	True of all the APPs – delete or replicate throughout.	Deleted
Section 3.5.1.2	Ramp manager/surface operators could also benefit from this information, which may increase safety assessment level.	Added
Section 3.5.2.4	Other technologies such as multilateration are also candidates.	Clarification Added
Section 3.5.3.1	Other technologies such as multilateration are also candidates.	Clarification Added
Section 3.6.1.1	FANS 1/A ADS-C and some level of CPDLC are in use today in NAT; communications are no longer limited to the HF system.	Clarification Added
OC14 (cost effectiveness)	NAT is already experiencing cost reductions by moving position reporting to ACARS-based ADS-C and data linked WPRs; these have relieved the pressure for new HF channels (delay/deferring implementation costs).	Added
Section 4.1.5	Should also take into account the level of system integration needed within each domain (air, ground) and between the domains - it is not clear if this is already included as part of the criteria.	It is included
Section 4.1.6 (Impact on airspace/airport design and management)	Need for mandates for forward fit and retrofit are politically very difficult – the level of severity should move up (from 2-3 to at least 3-4).	Addressed in Phase 2
Figure 4-1	For data link systems there is a ground-air system integration and test activity that may months/year(s) to the pre-operational approval stage.	Addressed in Phase 2

Paragraph No. version 1C	Comment	Action
Figure 4-1	An Industry Business Case alone is not good enough to move to implementation - each organization must then make their own business case, which may add a few years as issues such as individual organizational benefits are identified/allocated in such a way as to be suitable for a organizational CBA.	Discussed during the workshop – these separate processes were combined in order to simplify the model
Section 4.22 OC2	Why was 50% threshold chosen? Per L2k+ business case simulations, benefits start accruing as early as 25% equipage.	Reviewed and clarification added
Section 4.22 OC2 App2b (safety criticality)	Since APP2b is strategic messages, shouldn't this be a "1" (as is APP2a)?	Issue 2
Section 4.22 OC2 App2b (Impact on airspace design, management approval.)	I am not aware of any plans requiring segregated airspace for APP2b. Should this be a "1"?	Reviewed and amended
Section 4.22 OC2 (Critical path elements)	I don't concur that APP2b timescale is dominated by 'need to achieve high equipage' – reference earlier reference to benefits starting to accrue at 25 % equipage.	Reviewed and amended
Section 4.2.4 OC4 (Development Status)	D-ATIS has already been implemented over ACARS in 26 locations in Europe	Timescales amended
Section 4.2.6 OC9 (Impact on airspace design, management approval.)	Severity of potential certification issues imply a >2 assessment level.	Reviewed and amended
Section 7.2.1.1 App2b	Do not concur with 'Low" rating (ref my comments on OC2 summary of benefits table in section3).	Reviewed and amended
Table 7-1 Abb14b	It is unclear how ATS in oceanic/remote areas which mostly rated "small' benefits in section 3, rates "High" priority here.	Reviewed and amended
Section 7.3	APP2a and APP2b are listed as operational 2007 and 2004 respectively earlier in the document. Accordingly, they should be moved left to be under the 2004-2007 column.	Agreed and has been moved
Section 7.3.2	App2c and App4b are listed as operational 2010 earlier in the document. Accordingly, they should be moved left to be under the 2006-2010 column. App2d is listed as operation 2012 earlier in the document. Accordingly, it should be moved left to be under the 2011-2015 column.	As above
Section 8.1.6	ADS-B and TIS-B are listed as "services" later, but they aren't clearly tied to service here.	Reviewed during Phase 2
Acronyms	ACARS = Aircraft Communication **Addressing** and Reporting System	changed
Acronyms	ATN = Aeronautical Telecommunication Network (no s on Telecommuncation)	changed
Acronyms	FAA = Federal Aviation Administration	changed
Acronyms	PETAL = Preliminary EUROCONTROL Test of Air/ground data Link	changed

6.3.9 Eurocontrol (Alex Wandels)

Paragraph No. version 1C	Comment	Action
General	The term application is not used as normally in ICAO data link documentation (i.e. CM, ADS, CPDLC, FIS). This is very unfortunate for a document that treats data link applications.	We are not dealing with data link applications in the first part of the study – we have used the term ATM applications
General	There is an enormous range of data link services covered in the document from already implemented services, to vague ideas, not even supported by a concept (although grouped as OC). Although this is recognised in some parts of the document it, does not seem to be remembered everywhere.	Review carried out
General	ADS-B applications seem to be given the benefit of the doubt for both cost and benefit assumptions. Whilst it is recognised by everybody that some applications have a good potential, it is also known that some of the more advanced face major architectural/certification and hence cost problems.	Further consideration has been given to this in Phase 2
General	The document is covered with structures, codes and scores which give it a pseudo-scientific complexity, that is unfortunately not always supported by the content.	This approach has been accepted by other stakeholders and parts of the approach have been used by Eurocontrol in ADS work
In my area (CPDLC - LINK 2000+) I would like to add the following comments:	For OC2 in para 3 it is claimed that no benefits are identified, whilst CPDLC, together with DAPs (covered by the Mode S Programme) are probably the only ones of the OCs for which detailed CBAs (based on real cost and real benefits) have been conducted.	Issue 2
OC2	OC2 in 4 is full of inaccuracies and incorrect information, which can easily be corrected by reading the Master Plan for LINK 2000+.	A review has been carried out
OC2	OC2 is linked to LINK 2000+, but this programme is only addressing one or two of the listed services.	Other services are included implicitly – clarification added

6.3.10 Frequentis

Paragraph No. version 1C	Comment	Action
Section 2.1.3	: The data link cannot cover all (in particular tactical-) communications requirements, the most ATM applications will still require voice communications along with the data link. This fact should be emphasised (even if the focus of this work is clearly on the data link communications).	Taken account of in Phase 2
Section 3.1.5	Why is CDM constrained to just ground-ground interactions? CDM may be also applied in-flight, e.g. as AOC uplinking the preferred trajectory which in turn is T.B. negotiated with the ATS authority!	Issue 1

Paragraph No. version 1C	Comment	Action
Section 3.2.2.1	OC1 is strongly focused on surveillance data (only). What about using aircraft weather-sensors to improve the quality of ground weather forecasts? Adding such non-surveillance data to OC1 may require non-broadcast and non-SSR point-to-point data links!	Added
OC1 (capacity)	Some DAP-parameters can also be used by automated systems- it is an local issue, which parameters should be displayed to (and could overload-) the controller.	Clarification Added
OC1 (safety)	Does reducing false alarms really increase safety?	Reviewed
Section 3.2.3.3 (APP 2b)	Here a general reference to CPDLC would be probably more appropriate (DCL denotes a dedicated CPDLC data link service).	Agreed
Section 3.2.3.3 (APP 2c)	Which data link services are addressed here? An example would be helpfull!	Clarification added
Section 3.2.3.3 (APP 2d)	Currently, there is ongoing work on the COTRAC service.	Clarification added
Section 3.2.3.5	Not sure, whether at least parts of APP2a, APP2c could also use broadcast air-ground data link combined with the point-to-point data link?	Considered in Phase 2
Section 3.4.2.2 APP 9a	It would be fine to include examples for data link services here (as it was done for the most of the previously described ATM applications).	Added
Section 3.4.2.4	Except for the air-air broadcast data link, no dedicated data link services seem to be known by now (a part of the work could be done by using voice) and it will be the service QoS requirements which will ultimately define the type of the data link! The further concern is, if no data link services are known today, they may not be mature enough to be implemented by 2015!	Phase 2 issue
Section 3.4.3.4	See the comment on the p. 31!	
Section 3.4.4.3	It was explained later, what the cluster control means, but a brief description would be helpful here!	Clarification added
Section 3.4.4.4	See the comment on the p. 31!	
Section 3.5.2.4	In addition to the aeronautical "air-ground" ADS-B/ TIS-B data link, should it not be possible to use dedicated "ground-ground low-cost" ADS-B/ TIS-B data link for the ground vehicles with a kind of a gateway between such two systems?	Phase 2 issue
Section 3.6.2.3	The air-air broadcast is OK. Which kind of broadcast information would be uplinked (and how- via HF, via satellite?) from the ground for ATT14a?	Considered in Phase 2
Section 5.4.13.1	While ATSAW- and the most of other "new" applications were intentionally **developed** to increase safety, our concern is that not all aspects of their operational usage could have been tested so far- some of these aspects could even have adverse impact on the safety (e.g. increased head-down time, loss of party-line...).	Agreed and to considered further in Phase 2
Section 5.5.2	An indirect benefit of such "reverse" trend would be slowing-down the rate of new ATC frequency allocations which would otherwise run-out (even with 8.33 kHz expansion programmes) within the addressed time frame.	Note added
Section 6.2	Strong emphasize on ADS-B related initiatives. In our opinion, point-to-point data link can also provide significant benefits- e.g. via 4DTN.	Issue 9

Paragraph No. version 1C	Comment	Action
Section 8.2	The mapping of the application to the communications technology is a real challenge- it is expected, that this will be a part of the future work on this Study. In the following tables no specific constraints imposed by the considered application onto the communications technology have been indicated (e.g. ADS-B requires broadcast DL technology, while ADS-C requires point-to-point data link). In our opinion, it is essential to indicate such constraints as early as possible, as only several DL technologies are currently available and it takes long time to introduce-/standardise new technologies.	Phase 2
Section 8.2.1	Will this granularity (just three levels) be sufficient to decide later, whether a given technology is suitable for the service under consideration? In the past, some technologies had problems with ATM services at a detailed level (e.g. average message end-to-end delay acceptable, but the **maximum** end-to-end delay inacceptable...)	onsidered in Phase 2
Section 8.2.2 APP1e (Description of exchanges between protagonists (ATCO, pilot))	Cut-and-paste problem???	editorial
Section 8.2.2.1 APP2b D/L services	The selected structure of the table makes in some cases difficult to perform exact mapping of DL services onto DL applications, e.g. the DLIC (DLL) service uses the CM- instead of CPDLC (ATN) communications application.	Clarification added
Section 8.2.4 App4a (Operational (communication) applications)	Currently, the ATIS service is provided by using voice broadcast.	Noted
Section 8.2.5 OC7 (Operational (communication) applications)	Not traceable up to the D/L application level- neither ADS-C, nor CPDLC applications aim to provide flight information services?	Clarification added
Section 8.2.8 App11a (Description of exchanges between protagonists (ATCO, pilot))	Is the term "clearance" applicable between the pilots?	Considered in Phase 2
Section 8.2.8 App 11a	Is there any known DL service T.B. used for such air-air coordination?	Phase 2 issue
Section 8.2.10 APP13c D/L services	In this area, extended CPDLC seems to be more appropriate than ADS-B for delivering taxi-routes to the pilots!	Reviewed in Phase 2

6.3.11 Swedavia/LFV

Paragraph No. version 1C	Comment	Action

Paragraph No. version 1C	Comment	Action
General	ATSAW is the renaming of the US term CDTI. It is not an application, instead it is an enabler for e.g. ADS-B applications.	Agreed that it is an enabler – but it also appears to provide safety benefits and also, according to JAFTI, support for more efficient VMC
General	An important element that seems to be missing in the document (which is supposed to be used for e.g subsequent assessment of technologies) is the number of airports in Europe that are providing ATC services, and therefore will need data link equipment. In order to implement harmonised operational procedures all airports with ATC services and in particular those with schedule traffic will need provisions for data link services.	Added during Phase 2
General	Review and modify all dates stated for implementation of applications. Traditionally, planning dates beyond a five year period are so uncertain thet they are not worth mentioning. Therefore, it is suggested that instead of stating e.g. 2015 or even 2018 change all those to e.g. 2008+ since all applications discussed could be implemented within 5-6 years subject to directions and clearly expressed commitments. If the efforts used during the last 5-7 years to fight "political" rather than technical and operational issues, a lot could have been accomplished already today and significant amounts of money could have been saved for the aviation community.	Issue 8
Section 1.1.5	Time schedules need to be revised based on the comments provided in this document and to also comply with European neighbouring counties plans such as Russia since essentially all traffic between Europe and the Far East is crossing Russian airspace. The possibility to open Polar Routes through Russian airspace represents significant savings to the airlines. Russia plans to have ADS-B VDL 4 implemented by the end of 2005.	Issues 6, 7 and 8
Section 1.2.1	Stakeholders opinion need to be wider and include e.g. those now provided by Swedavia/LFV's and results of other relevant surveys done under CEC sponsored projects, e.g. by MA-AFAS and MFF.	Further consultation will be carried out
General	The document is well written and structured; However, the assessments need to take into account the situation outside of Core Europe where the assessed benefits may be quite different to the busy areas. Most of the global airspace is providing poor or limited ATM Services, yet representing the main parts of a cross-continental flight.	Issue 11
Section 2.1.3	"Technical requirements" need to address not only ATM applications, they should also include the airborne side since the main investment for implementation is on the aircraft (air transport, GA, etc) and for ground surveillance also the ground vehicles. The subsequent assessment of the airborne side should include e.g. the possiblity for a certain technology to provide Gate-to-Gate functionality, possibility to co-exist on the same aircraft, how availability requirements for ADS-B can be met, whether a technology can operate and perform on different types of user vehicles including G/A, soaring airplanes, ground vehicles, etc.	Phase 2 issue

Paragraph No. version 1C	Comment	Action
General	When assessing the economic benefits of ADS-B and data links it is neccessary to determine the baseline for the comparison. Traditionally such base-lines have assumed that a program that is started or on-going together with all other systems already deployed forms the base-line for comparisons. However, this often gives a completly wrong result. There should be a trade-off type of comparison; As a few examples the following can be mentioned: Current Eurocontrol supported policy and programs suggests dual SSR/MSSR/Mode S for surveillance complemented with PSR in high density TMA's while the surveillance information is depending on a single thread on-board system; An ADS-B infrastructure would cost a maximum of 15-20 % of a radar infrastructure: Link 2000+ based on VDL Mode 2 that will provide very limited functions and exhibits uncertain/unlikely deployment feasibility is quoted to cost the airlines 150,000.- US$ per aircraft. A VDL Mode 4 installation onboard an aircraft would cost less, yet providing both ADS-B and AOC capabilities plus priceless spectrum savings. Continued under comment 7 below.....	Comments noted for consideration during Phase 2
General	Current Eurocontrol policy also suggests installation of TCAS/ACAS on aircraft with 19-30 seats by 2005. Since the TCAS/ACAS equipment cost more than the second hand values of those aircraft they are likely to go out of business if the Mandate is executed. A less costly ADS-B system will provide also the CD&R functions to those aircraft plus a lot more!! There is an urgent need to start to apply systems wide views when assessing cost-benefits!	Comments noted for consideration during Phase 2
General	Consider changing "Heading" to "Track" wherever applicable because it is basically not so interesting to know in which direction the aircraft nose is pointing, it is more valuable to know where the aircraft is actually going. There are three different types of headings; True Heading, Magnetic Heading and Compass Heading. The reason why heading is used is that it traditionally are the values that the pilot can read from his compass and report over R/T. With the new systems in place "Track" will also bee seen in the aircraft.	To be considered
Section 2.3.2	Figure 2.2.: The boxes under Airborne spacing; Add "Crossing and passing in En-route and Terminal Area airspace.	Will be added
Section 3.1.5	The exclusion of e.g. CDM must be based on a mistake in the study and should be corrected.CDM (Collaborative-Decision-Making) is in our opinion not a ground-ground application; It is an air-ground application with the "pilot-in-the-loop"	Issue 1
Section 3.2.2.7	Last line: …where there is unlikely to have any radar coverage (instead of extensive)	To be changed
Section 3.2.2.9	Expected dependencise on data link: You need also Ground to Air broadcast for GNSS Augmentation (at least at high latitudes; e.g. in Finland, Norway and Sweden where EGNOS in Geosynch. Orbits is at too low elevation angles) and for TIS-B during the transition to full ADS-B equippage.	To be added
OC1	Cost effectiveness: Assuming reduction of current dual SSR/MSSR/Mode S coverage "requirements" in accordance with current Eurocontrol policy the cost effectivness of APP 1d and 1e becomes high. See comments 8 and 9 above.	Benefit level to be reviewed
Section 3.2.3.5	For those applications you will need an air-air and air-ground data link; with both broadcast and point-to-point capability depending on the finally agreed technical procedures for Trajectory Negotiations.	Comment to be added to make this clear
OC3	ATSAW is the renaming of CDTI. It is not an application, instead it is an enabler for e.g. ADS-B applications. In e.g. The MFF-project further work on ATSAW has been stopped, but ATSAW will be implicitly evaluated together with applications.	Noted – but we have chosen to look at the benefits associated with just ATSAW

Paragraph No. version 1C	**Comment**	**Action**
OC4	Provision of D-ATIS, etc. is potentially a large Cost Effectiveness area in particular for the airlines. A broadcast of D-ATIS instead of using ACARS could lead to cost savings on the order of one (1) million US$ at a single busy European airport is the provision of information is done over a broadcast link instead of current communications charges. Additionally, in poor weather conditions on-line updates to the aircraft of e.g. RWY braking action and RWY Visual Range (RVR) can minimise holding times. Access to D-ATIS through a point-to-point data link will also help the pilot to determine the alternate airport en-route. Suggest Medium Cost effectiveness on both APP4a and APP 4b. On environmental impact you could also add potentially reduced holding times in poor weather conditions.	Will be incorporated into the document
OC7	Availability of real time information of traffic can improve the efficiency of the European Flow Management functions and thereby increase capacity. It is also surprising to note that there is no Cost Effectiveness identified despite that Flight Efficiency is assessed as Medium. Suggest changes. In remote areas availability of new routes enabled by e.g. ADS-B could represent very significant savings by shortening Flight times.	To be reviewed
Section 3.3.5.2	Development of a reliable and useful MTCD tool is very much dependent on the exchange of aircraft Intent Information. Basing development of MTCD on "historical" radar tracks, starting with a best accuracy of a 0.25 nm circle and guessing where the aircraft might be a few minutes ahead is bound to fail - and has done so!	Noted and a clarification will be added
Section 3.3.5.4	Exchange of Intent Infromation requires data link.	Clarification to be added
Section 3.4.3.4	Why "in addition to current infrastructure"?? Some current infrastructure may be withdrawn.	To be reviewed
OC10	Disagree totally with the assumption that Capacity gains with APP10a is small. Should be Medium or Large. If you can reduce current separation standards from 60 nm. in the North Atlantic and 15 minutes in most other areas to let's say 10 or even 30 nm. the capacity gains are Large. That's what ADS-B could offer. Also disagreeing with the Cost Effectiveness statements. First there is a direct correlation between Flight Efficiency and Cost Efectiveness, secondly e.g. for 10a aircraft en-route Europe-Far East are often short of fuel resources (e.g B-767). In cases where it is not possible to get the optimun altitudes due to other traffic it often lead to refulling e.g. in Moscow and/or reduced payload. That's a costly excersise!	These illustrations will be used and a review of the benefit level carried out by the consortium
Section 3.4.4.4	Air-to-air Point-to-Point data link is very likely to also be needed for air-air trajectory negotiations.	Noted and information will be added to the report
OC11	APP 11b. Change the "Core airspace" to high density airspace and thereby widen the horizon. Assuming the implementation of Free Flight in "High Sea" airspace there are enormous potential savings for the airlines. If you don't require any services the airlines wouldn't have to pay user fees to ATM providers. In e.g. the North Atlantic that represents significant savings!!	Noted and will be added to report
Section 3.5.1.4	As long as Link 2000+ is associated with VDL Mode 2 any and all references to Link 2000+ should be deleted, at least until Eurocontrol or anyone else has proven the feasibility to implement VDL 2 given the number of airports, spectrum consequences and constraints.	Document to be reviewed to assess impact of this
Section 3.5.2.4	To provide those applications you also need an aircraft-ground vehicle broadcast data link. Otherwise you miss almost the whole purpose of those applications. There are more ground vehicles than aircraft at most airports.	Clarification to be added

Paragraph No. version 1C	Comment	Action
OC13	This page requires a lot of rework. A NASA study has clearly stated that a CDTI/electonic map/ and situation awareness can potentially speed up the movement of aircraft by 30-50 % during low visibility conditions. The most costly parts of damage rapairs to aircraft are due to collisions on the ground. The most devastating accidents in aviation has happened on the ground. In the US there is on avarage one (1) serious Runway Incursion incident per day some of those leading to fatal accidents. In the Far East we recently had the Taiwan accident, In Europe the Milan Accident, etc..Compare the cost of a Ground radar (that can't provide unambigious tagging of a vehicle) with an ADS-B system (that can do 10+ more applications) the cost effectiveness will change. APP13b will not provide any situation awareness into the cockpit and how will you get surveillance information from ground vehicles? Save the money on Multilateration. GBAS as currently defined is using circular polarization and will therefore add cost and complexity e.g for ADS-B on GA and ground vehicles. The correct term to be used instead of GBAS is GRAS.	Issue 13
OC14	See comments under comment 14 above since it is difficult to separate those applications from a practical/operational point of view. Furthermore: If ADS-B is implemented with an event triggering of an ADS-C message the number of ADS-C messages could be reduce thus leading to significant savings of communication charges over the SATCOM link, and may even make that redundant! Cost effectiveness would then become HIGH.	Comment will be considered and OC14 changed accordingly
Table 4-2	Existance and availability of ETSI/EN's seems to have been forgotten.	To be added
OC1	It is VERY difficult to see how the description on this page is related to the task of the Study. 1.) Mode S is not a data link; 2.) Mode S Enhanced Surveillance has been rejected by the majority of airlines and by the entire G/A community; 3.) Mode S is not ADS-B capable due to availability constrains, limited range, limited capability (worse cases are ground applications and for GA, etc.Tests in the USA on GA aircraft a three locations demonstrated a range of generally 3-4 nm. and sometimes up to 10 nm.; In resulution 20/5, September 2000, IAOPA at its 20th World Assembly "urge(d) State regualtory aothorities to not require installation of Mode S transponders"....), and a vast of money for the ATM Providers, the airlines and the GA community. Mode S has not been standardised for ADS-B applications. What is proposed for ADS-B is the Mode S Squitter and that requires a completly new ground infrastructure since IT IS NOT COMPATIBLE WITH MODE S Elementary Surveillance radar stations. This page requires a complete REWORK!	The words will be reviewed to make them more acceptable
OC1	Time schedules are politically driven and not technically or operationally. As an example integration of ADS-B data was made in Padua, Brindisi and Rome under the CEC sponsored FARAWAY II-project over a two year period including intra center networking, TIS-B, GRAS, CPDLC, etc. It almost looks like the time schedules are developed to protect industrial interests rather than the interests of the aviation community. To state that there are no tasks completed is also completely misleading and false information. ADS-B standards for VDL Mode 4 (ICAO, Eurocae and ETSI) are completed and equipment are available as opposed to Mode S Squitter.	To be reviewed
OC2	See comments under comment 17 above. Completed tasks are incomplete. SARPs for VDL Mode 2 are still being amended despite 10 years of work, ETSI standards are missing and the possibility for wide deployment not properly investigated. ACARS and VDL Mode 2 are not suitable for any ATC applications except for some non time-critical applications in remote areas (ADS-C). However, this could be made better and more economical if ADS-B/VM4 was used in combination with the SATCOM link (ADS-C) as requested by the ICAO Air Navigation Committee. Previous business case presented in Link 2000+ for VDL Mode 2 suggested a break-even after 2009/2010 based mainly on benefits from reduced delays. How VDL Mode 2 could reduce delays could not be answered and understandable explanations are still pending.	Technology issues to be addressed in Phase 2

Paragraph No. version 1C	Comment	Action
OC3	First aircraft equipped with ADS-B was 1985; the second 1989 and during the 1990's 50+ aircraft and some 50 ground vehicles were equipped with the second and third generation of ADS-B transponders. USAF equipped seven (7) C 5 Galaxy aircraft with VM4 transponders in 1995 and have used them operationally since 1996. SARPs compliant equipment was first developed and available in 1999, and standards compliant production units are available since 2001 (developed under the CEC sponsored NUP II).	Phase 2
OC4	LFV is planning to have the operational services available end of 2005. If Link 2000+ is planning to associate this services with VDL Mode 2 see comments under comment no. 17. Successful trials have been performed in Italy (FARAWAY II), Spain (SUPRA) and Sweden (NEAN/NEAP).	Phase 2
OC9	Why differences in time schedule between operational approvals of APP 9c and APP 9d, and why the gap between operational approval and operational. Scedules are too long, and should suggest Operational in 2006.	Explanation to be provided
OC10	Time to implementation too long. See also comments under General no.3. How could FANS installations support ITC/ITD? What is likely referred to is the unapproved procedure to use TCAS (by switching on/off for identification) for ITC/ITD. This has nothing to do with FIR equippage and FANS. Use of FANS/SATCOM can not be correct, and if it is, it requires some explanations before it is entered into the table.	Issue 8
OC11	Time to implementation too long.	Issue 8
OC12	There is no necessary linkage between TIS-B and ADS-B on the ground.	Clarification to be added
OC13	Time to implementation too long. See comments under General no.3.Development Status: all equipment standards required are available. Has been successfully tested since 1991 in Sweden and subsequently in the CEC sponsored projects like NEAN/NEAP, SUPRA and MAGNET-B. LFV is working towards certification during late 2002.	Issue 8
OC14	Time to implementation too long. See comments under General no.3 and 4. Delete comments from CENA until the implementation issues for VDL Mode 2 is clarified, since CENA is advocating this technology for CPDLC.	Issue 8
Section 5.2.2.3	We guess that the number of passengers should be 2 billion.	Information to be incorporated
Section 5.4.6.14	Reduction of sector size also increases pilot workload. Today, in Core Europe one of the pilots is very busy with changing frequencies and ATM communications. Very likely it is more than 5 minutes per hour. Results from MFF Fast Time Simulations could add data on that.	Clarification to be added
Section 5.4.9.9	"Only one other aircraft should be involved"; This prerequisite is not necessary true. Actual flight tests made in Swedish airspace, February 1999, with four (4) aircraft involved demonstrated good possibilities for conflict resolution provided that: Trajectory Change Points (or Next Waypoints) are transmitted/exchanged between aircraft, and the use of a CDTI indicating Conflict as well as potential Conflict areas.	Clarification to be added
Section 5.4.9.10	Those assumptions related to the role of the GND systems may only be partially relevant. If TCP's are exchanged between aircraft the GND system may not have to be involved in the co-ordination. However, there is a need for TCP's also on the GND for a variety of other reasons. The GND systems have a role to uplink various forms of information of which Arrival Time over e.g. an Arrival "fix" is one.	Clarification to be added
Section 5.4.9.11	Information to the pilot can also be filtered in the onboard display as was done and demonstrated in e.g. the FARAWAY II-project 1999-2000.	Information to be added to report

Paragraph No. version 1C	Comment	Action
Table 5-14	The time schedule for introduction of the various applications are too conservative. Provided that some groups in Europe could be convinced of "not having to exhaust every other alternative, before doing the right things" (Sir Winston Churchill) Europe could lead the introduction of the new ATM concept and have it done within 5-7 years.	issue 8
Section 5.4.11	Limited delegation to pilot for e.g. Final approach spacing can potentially increase the runway throughput quite a lot. Several studies at e.g.Chicago O´Hare airport has shown that there is a wide difference between the touchdown times on the runways, which clearly indicates that separation on final approach varies quite a lot, while runway occupancy times are relatively constant between 45 - 65 seconds. Of cause, due considerations have to be taken to the Wake Vortex problems, but between narrowbody a/c there seems to be possibilities to increase the runway troughput. Pilots have much better possibilities to maintain a predetermined time/or distance to precceding a/c than controllers (who is controlling a number of a/c and normally add some margins to the minumum separation). This is also well presented in the subsequent paragraphs of this section.	Comments noted
Section 5.4.12.5/6	The most important thing here is that data link/ADS-B will provide unambigious identification of targets on the airport surface to both pilots and controllers. This is not possible without ADS-B.	Clarification to be added
Table 5-15	Time schedules for introduction of applications generally too conservative.	Issue 8
Table 5-16	APP12a; Swedish CAA is working towards certification of an ADS-B based A-SMGCS with S-EVA in several vehicles planned to be completed before the end of 2002.	Information to be added to report and used in Phase 2
Table 5-17	Time scedules far too conservative. Fusion of ADS-B and Radar was first demonstrated with single radar stations in Gothenburg, Sweden in 1992 and in Italy in 1997. In 1999 and 2000 it was demonstrated and evaluated with multiple and overlapping radar stations in Italy (FARAWAY II). Why does that need to take another 6-8 years? All applications, especially APP10a, APP14a and APP14b has Large Cost Effectiveness. Imagine deployment of radar stations in e.g. Siberia instead of ADS-B!	Issue 8
Section 5.5.4	See comments on section 5.4.9.9	
OC12	(ATSAW?) Ground Surveillance: There is a need for TIS-B in connection with ADS-B on the Surface only during a transition phase with limited functions since the Ground Movement radar does not provide Indentity of the radar targets. If ADS-B had widespread use there would be no need for Ground Movement Radars (GMR)! Fusion of radar (where GMR exist and are maintained in operation) and ADS-B data is also required for ATM and is also a "requirement".	Information noted

6.3.12 CNS

Paragraph No. version 1C	Comment	Action
General	In general all applications should be link independent in at this time. Link 2000+, Mode S etc should not be mentioned.	Document to be modified
General	It is very important when 'complement to existing infrastructure' to separate Mode S from Mode S squitter as the latter needs a complete new infrastructure both in A/C and on ground.	Noted
General	Time scale in most cases are too long	Issue 8

6.3.13 Qinetiq

Paragraph No. version 1C	Comment	Action
General	My overall impression is that the document contains a good compendium of the traditional data link services - as identified in MACANDO.	
General	The statement in the note in section 3.1.5 'that the terms of reference of the study deals with identification of ATM applications which may require a data link. Therefore the focus is on air/ground and air/air ATM applications and therefore ground-ground applications such as collaborative decision making (CDM) have not been considered' is disturbing as several studies have shown that data link usage at airports can have benefits for the operation of an aircraft. I have not seen any mention of the gate-to-gate concept (I guess you would it is assumed in the various strategy documents) but I think that there are is a potential here for strategic benefit in handling aircraft even before they get airborne.	Issue 1
General	I think the timescales for the development of the safety case is rather optimistic. For each, an operational context needs to be in place and there does not seem to be agreement on this for some of the applications you mentioned. Also will a safety case be undertaken on a State basis or regional basis. The latter would be preferable but that will be difficult.	Issue 8
OC1 (capacity)	This does not indicate what the benefits are but how they will be generated.	Clarification to be added
OC1 (Flight Efficiency)	This efficiency will only be realised if aircraft are allowed to follow their flight plans – this is a procedural or conceptual requirement.	Clarification to be added
OC2 (capacity)	Increased productivity and efficiency does not lead to increased capacity. It leads to ATCos being able to handle more aircraft and hence handling a bigger sector but does not increase the capacity of a sector.	???
OC4 (capacity)	Again – this doesn't increase capacity	???
Section 5.4.6.14	There is a limit to this. The size of sector has to be sufficiently large to ensure that the 'control' time is a significant proportion of the hand-over time. Also there are limitations on frequencies.	Clarification to be added
Section 5.5.4	Multiple conflicts can be broken down into conflict pairs – each pair being solved by a single resolution manoeuvre. This means that multiple conflicts do not actually exist. The problem is passed on to the resolution process which must avoid all aircraft whether conflicting or not.	Clarification to be added
Section 8.1.5	How can pilot-pilot comms be considered an ATC service ?	True – but it is an ATM service – wording to be changed

6.3.14 NATS

Paragraph No. version 1C	Comment	Action
General	The input documents have reached very high quality.	

Paragraph No. version 1C	Comment	**Action**
General	The timescales quoted are very very ambitious, we don't think that most of the applications will see operational use this side of 2010. Talk of safety cases for OC3 (ATSAW) in 2003 and OC4 (Provision of information to a/c) in 2004, when the industry itself is in major recession and the benefits this document suggests are marginal, makes these timescales totally unrealistic. An additional 5 years would correct most estimates.	Issue 8
General	There is a perceived 'bias' towards ADS-B and away from ADS-C. In quite a few applications, the potential use of ADS-C is played down and benefits delivered via ADS-B. Whilst this is a known view within various States and Organisations, it is not necessarily unanimously endorsed, both applications have strong and weak areas. Again, a longish list of comments could be supplied, but it is almost certainly not worth it at this stage of the Project - the issues have not been resolved between the two 'camps' in the last few years and it is very unlikely that this Project could achieve it either.	Noted and will be taken account of reviewing the document

7 ATM application timeline

7.1 Introduction

7.1.1 Leading on from the results of Phase 1, this section presents a timeline for ATM application implementation.

7.1.2 The main focus of Phase 2 will be the derivation of an appropriate technology roadmap focussing on those ATM applications that must be supported in 2010. It is also required to look at technology options for the shorter term and a period up to 2006 (ie half way between the present and 2010) has been taken as the end of this short term period. Finally, account must be taken of possible ATM application developments in the longer term up to the end of 2015.

7.1.3 Therefore the ATM applications have been grouped in time as follows:

- Those achieving widespread operational status by the end of 2006.
- Those achieving widespread operational status by the end of 2010, divided into two subgroups:
    - capable of introduction before the end of 2006;
    - more likely to be introduced after 2006.
- Those achieving widespread operational status by the end of 2015, divided into two subgroups:
    - capable of introduction before the end of 2010;
    - more likely to be introduced after 2010.
- Those not achieving widespread operational status until after 2015 but capable of introduction before the end of 2015.

7.1.4 The introduction time for an ATM application is taken to be the operational approval milestone. Increased use of the ATM application occurs through the transition period and widespread operational status is assumed to occur at the operational milestone.

7.1.5 The ATM applications are prioritised according to the following scheme:

- HIGH: these ATM applications should take the highest priority for development and implementation actions. Section 5 highlighted that the most urgent need is to provide sufficient capacity to meet future demand in core ECAC airspace. Therefore, this priority level has been assigned to ATM applications which contribute to provision of capacity. Note that, in accordance with the results of Section 5, preference is given to a) those ATM applications, listed in Table 5-14, which lead to increased delegation to the pilot in en-route areas and b) those ATM applications, listed in Table 5-15, which support enhanced capacity in the terminal and airport region.
- MEDIUM: This level has been assigned to ATM applications which enhance safety, promote the flexible use of airspace through provision of flight information, and offer opportunities for cost saving.
- LOW: This level has been assigned to those ATM applications which do not appear to offer significant benefits. This includes those applications which

have been listed as SMALL (but not NONE) in terms of capacity, safety, flight efficiency, cost effectiveness or enablers in Section 3 and which are not part of the measures that lead to a progressive enhancement of capacity as listed in Table 5-14 and Table 5-15.

7.1.6 This section will be revised during Stage 2 in the light of prioritisation and adjustment to timescales resulting from stakeholder consultation including the Stakeholder workshop. Further refinement of the timeline will occur as a result of the technology assessments carried out in Phase 2.

7.2 ATM application timeline

7.2.1 Widespread operational status by the end of 2006

7.2.1.1 Table 7-1 lists the ATM applications that could gain widespread operational status by the end of 2006.

#	ATM application	Region of applicability	Timescale (intro. – wide usage)	Priority
APP1a	Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller	en-route, transition, terminal, approach, departure, surface	2004 – 2005	MEDIUM – provides small increase in capacity in short term
APP2b	Strategic controller/pilot messages	en-route, transition, terminal, approach, departure, surface	2002 – 2004	HIGH – part of capacity enhancement roadmap for terminal and en-route
APP3b	Enhanced visual acquisition (EVA) in terminal airspace	terminal, approach, departure	2005 – 2006	MEDIUM – supports increased arrival rate [116] + safety
APP3c	Enhanced visual approaches	approach	2005 – 2006	MEDIUM – supports increased arrival rate [116] + safety
APP4a	Provision of D-OTIS (ATIS, METAR) and D-RVR	en-route, transition, terminal, approach, departure, surface	2002 – 2004	MEDIUM – supports flexible use of airspace
APP14b	ATS in oceanic/remote areas	remote en-route, oceanic	2004 – 2004	HIGH – current ATM application supporting enhanced efficiency

Table 7-1: ATM applications: widespread operational status by the end of 2006

7.2.1.2 This package of ATM applications delivers low levels of direct benefit including:

- a small reduction in controller workload via transfer of some strategic controller/pilot dialogue to data link;
- higher movement rates particularly during low visibility;
- improved flight profiles in the oceanic region;
- safety benefits including a reduction in misunderstanding of controller messages and enhanced visual contact.

7.2.1.3 The key benefit, however, is the support for confidence building in the underlying technologies and for use of new control ATM applications, notably:

- performance of ADS-B technologies including monitoring of anomalous position reporting;
- early confidence in the use of air/ground data link including, for example, impact of loss of party line, controller working position design, cockpit interfacing etc.
- early confidence in the use of air derived data.

7.2.1.4 Realisation of the ATM applications in this package is supported by the following factors:

- there is no fundamental change to control responsibility;
- the new ATM applications are backed up by reversion procedures based on current technologies and procedures;
- operation in the Oceanic region is supported by extension of a current technology;
- extensive trials and development work has already been carried out on the ATM applications;
- there is likely to be a strong commercial drive for the early air/ground point to point data link to support strategic messaging based on provision of non-ATS communication services.

7.2.1.5 The key risks to effective implementation, the mitigating actions and the key decisions are summarised in Table 7-2:

Risk	Mitigation	Key decision/action
High equipage requirements for downlinked data	Elementary surveillance mandate produces high equipage by 2005	None
Modifications to CWP/RDP/ground networks	Required modifications already defined and trialled	None
Airborne integration for communication systems	Downlink of airborne data covered by elementary surveillance mandate	None
Moderate equipage levels required for early air/ground communication	Driven by commercial uses of data link. Expect equipage on fleet by fleet basis particularly for fleets operating from hub airports	None
Requirement for TIS-B system to support early ATSAW ATM applications	Prototype systems already exist (eg NUP). TIS-B requirement is for local terminal area (simplifies system requirements). Alternative is for mandate – but this could not be achieved within such short timescales	Consider if mandated approach is preferable to TIS-B (drawback of mandated approach would be delay to overall ADS-B related programme) Consider mandate for later ATM applications or if early introduction could be promoted by equipage of individual fleets operating out of a hub airport
Cockpit systems need upgrade to provide communication interface and CDTI	Based on existing prototypes	Investigate status of airborne equipment for communication and ATSAW ATM applications
Onboard integration of navigation and surveillance	Becomes more important in later ATM applications – at this stage,	Carry out ongoing monitoring of ADS-B system performance to build

	ATM applications have low safety criticality and hence early implementation provides confidence building	confidence accuracy, integrity etc

Table 7-2: Risks, mitigation, decisions and actions for ATM applications: widespread operational status by the end of 2006

7.2.2 Widespread operational status by the end of 2010

7.2.2.1 Table 7-3 lists the ATM applications which could be introduced before the end of 2006 and gain widespread operational status by the end of 2010.

#	ATM application	Region of applicability	Timescale (intro. – wide usage)	Priority
APP1b	Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs	en-route, transition, terminal, approach, departure, surface	2005 – 2007	HIGH – part of en-route and terminal capacity enhancement roadmap
APP1c	Enhanced surveillance accuracy for automation tools in terminal and en-route airspace	en-route, transition, terminal	2005 – 2007	HIGH – part of en-route and terminal capacity enhancement roadmap
APP2a	Pilot preferences data link	en-route, transition, terminal, approach, departure	2006 – 2007	MEDIUM – supports flexible use of airspace
APP9a	Airborne spacing in en-route and terminal airspace	en-route, transition, terminal	2006 – 2009	HIGH – part of en-route and terminal capacity enhancement roadmap
APP9b	Crossing and passing in en route airspace	en-route, transition, terminal	2006 – 2009	HIGH – part of en-route capacity enhancement roadmap
APP9c	Final approach spacing	approach	2005 – 2007	HIGH – part of terminal capacity enhancement roadmap
APP9d	Departure spacing	departure, surface	2006 – 2009	HIGH – part of terminal capacity enhancement roadmap
APP12a	Surface enhanced visual acquisition	approach, departure, surface	2006 – 2007	MEDIUM – safety
APP12b	Runway and final approach occupancy awareness	approach, departure, surface	2006 – 2007	MEDIUM – safety
APP13b	ATC surveillance using ADS-B at airports.	approach, departure, surface (small airports)	2006 – 2009	MEDIUM – provides ATC service at small airports – assess on case by case basis

Table 7-3: ATM applications: introduction before end of 2006/widespread operational status by end of 2010

7.2.2.2 Table 7-4 lists the ATM applications which could gain widespread operational status by the end of 2010 but are unlikely to see introduction until after 2006.

#	ATM application	Region of applicability	Timescale (intro. – wide usage)	Priority
APP1d	Fusion of current radar and ADS-B surveillance in terminal and en-route airspace	en-route, transition, terminal	2008 – 2010	MEDIUM – may offer cost effectiveness benefits in some regions
APP2c	Support for increased automation	en-route, transition, remote en-route, oceanic, terminal, approach, departure, surface	2008 – 2010	HIGH – part of en-route, terminal and airport capacity enhancement roadmap
APP3a	Enhanced visual acquisition (EVA) in remote and oceanic airspace	transition, remote en-route, oceanic	2007 – 2008	MEDIUM – safety
APP3d	Traffic situational awareness in core and transitional en-route airspace	en-route, transition	2007 – 2008	MEDIUM – safety
APP4b	Provision of full range of uplink information services	en-route, transition, remote en-route, oceanic, terminal, approach, departure, surface	2009 – 2010	MEDIUM – supports flexible use of airspace
APP7a	Provision of information on route availability (DYNAV)	en-route, transition, terminal, approach, departure, surface	2007 – 2009	MEDIUM – supports flexible use of airspace
APP10a	Airborne separation in oceanic and remote airspace	transition, remote en-route, oceanic	2008 – 2010	MEDIUM – efficiency benefits in remote and oceanic airspace
APP12c	Enhanced IMC airport surface operations	approach, departure, surface	2007 – 2009	HIGH – part of airport capacity enhancement roadmap
APP13a	Fusion of current terminal and/or surface radar with other surveillance means	approach, departure, surface	2007 – 2009	HIGH – part of airport capacity enhancement roadmap
APP13c	Routing	approach, departure, surface	2008 – 2010	HIGH – part of airport capacity enhancement roadmap
APP14a	Basic surveillance infrastructure via ADS-B in remote regions	remote en-route	2008 – 2010	MEDIUM – cost effectiveness assessed on case by case basis

Table 7-4: ATM applications: introduction after 2006/widespread operational status by end of 2010

7.2.2.3 This package of ATM applications delivers significant levels of direct benefit including:

- significant reduction in controller workload via transfer of tactical controller/pilot dialogue to data link, delegation of some controller tasks to pilots, transfer of some aircraft to conflict free routes and via a reduction in false alarm rate from controller monitoring tools;

- enhanced ground operations including reduced ground holding times, higher movement rates during low visibility and delivery of routing information via data link;
- improved flight profiles in the oceanic and continental region, in particular, facilitation of flexible airspace usage leading to a greater availability of user preferred trajectories and support for eg step climbs in the oceanic region;
- safety benefits including an enhanced airport surface picture, reduction in the risk of runway incursions and a further reduction in misunderstanding of controller messages;
- potential ground infrastructure costs savings if ADS-B data is used to supplement existing radar data.

7.2.2.4 A further benefit is the support for confidence building in the underlying technologies and for use of new control ATM applications, leading to the next phase of ATM applications, notably:

- performance of ATM applications based around ADS-B technologies including gaining experience of delegating tasks to pilots, monitoring separation adherence etc;
- confidence in use of air/ground data link for tactical messages including, for example, impact loss of party line, controller working position design, cockpit interfacing etc.

7.2.2.5 Realisation of the ATM applications in this package is supported by the following factors:

- although there is a significant redistribution of tasks between the controller and the pilot there is no fundamental change to responsibility for separation in en-route and terminal areas;
- new ATM applications in the airport, terminal and en-route regions are backed up by reversion procedures based on current technologies and procedures;
- the ATM applications could be implemented via business cases associated with fleet equipage (although there may be a need for mandate to speed up the rate of equipage);
- extensive trials and development work are ongoing on the ATM applications.

7.2.2.6 The key risks to implementation, the mitigating actions and the key decisions are summarised in Table 7-5:

Risk	Mitigation	Key decision/action
High equipage requirements for downlinked data	Mandate for DAP equipage currently being considered	Decide whether mandate for DAP equipage is required
Modifications to CWP/RDP/ground networks	Greater use of automated communication must be facilitated. Trials have been carried out on suitable technology but required upgrade may be incompatible with existing control suites.	Determine if development work requires further funding
Implementation of ADS-B ground station network serving en-route region and providing safety critical services	Required if ADS-B data used as an alternative means to achieve multiple surveillance coverage Note that mitigation is reversion to single or double radar coverage if ADS-B network fails (lowers criticality)	Use of ADS-B for multiple surveillance coverage is an alternative approach to extension of radar network. Decide whether both approaches should co-exist and, if so, which regions will adopt an ADS-B approach
Onboard integration of navigation and surveillance for safety critical applications	Most critical ATM applications are: Use of ADS-B for separation in oceanic regions Use of ADS-B data to supplement radar data Spacing ATM applications carry a lower safety criticality but confidence in system performance is still very important. Mitigation is that ATM applications have back up procedures based on current technology although the reversion procedure in oceanic needs to be decided	Carry out ongoing monitoring of ADS-B system performance to build confidence accuracy, integrity etc Design reversion procedures Address approvals issues and put in place a process for certification and approval
Requirement for TIS-B system to support ATM applications and/or need for high ADS-B equipage	Implementation of spacing ATM applications requires either high equipage rate or wide area TIS-B solution. Prototype TIS-B systems already exist (eg NUP) but need further validation over wide area. Alternative is for mandate	Decide if mandated approach is appropriate taking account of: whether this is preferable to TIS-B high ADS-B equipage is desirable to achieve the maximum benefits
Cockpit systems need upgrade to provide communication interface, CDTI and spacing tools	Based on upgrade of equipment used in earlier ATM applications	Consider maturity of avionics and plans for development
New airspace management processes required to support flexible routing and FUA	Institutional issues need to be addressed and flexible interfaces between states and with military established. Part of existing plans for development of airspace design	Monitor and encourage development of FUA policies
Changes to control procedures	Significant changes to control task necessary. Based on previous or current development and trials work.	Monitor and encourage development and trials leading to validation of new control tasks Design reversion procedures (includes need to decide on appropriate reversion procedures in oceanic region ie voice and/or ground surveillance via FANS) Address approvals issues and put in

		place a process for approval of new ATM applications

Table 7-5: Risks, mitigation, decisions and actions for ATM applications: widespread operational status by end of 2010

7.2.3 Widespread operational status by end of 2015

7.2.3.1 Table 7-6 lists the ATM applications which could be introduced before the end of 2010 and gain widespread operational status by the end of 2015.

#	ATM application	Region of applicability	Timescale (intro. – wide usage)	Priority
APP2d	Trajectory negotiation	en-route, transition, remote en-route, oceanic, terminal, approach, departure, surface	2009 – 2012	HIGH in terminal area – part of terminal capacity enhancement roadmap. Note that this consists of delivery of conflict free paths through terminal area. LOW elsewhere (delegation to pilot preferred to conflict free trajectories – see Section 5.4)
APP13b	ATC surveillance using ADS-B at airports.	approach, departure, surface (busy airports and TMAs)	2010 – 2013	LOW – expect busy airports to be equipped with radars and APP13a is more appropriate

Table 7-6: ATM applications: introduction before the end of 2010/widespread operational status by the end of 2015

7.2.3.2 Table 7-7 lists the ATM applications which could gain widespread operational status by the end of 2015 and which are unlikely to be introduced until after 2010.

#	ATM application	Region of applicability	Timescale (intro. – wide usage)	Priority
APP1e	ATC surveillance using ADS-B in terminal and en-route airspace	en-route, transition, (terminal)[13]	2011 – 2015	MEDIUM – cost effectiveness assessed on case by case basis. Note that unlikely to play a role in busy terminal regions where there is likely to be radar in place

[13] Stakeholders have commented that it is unlikely that an ADS-B only solution could be implemented in busy terminal areas – there is a belief that radar will always be necessary.

#	ATM application	Region of applicability	Timescale (intro. – wide usage)	Priority
APP10b	Airborne separation in en-route and terminal airspace	en-route, transition, terminal	2011 – 2015	HIGH – part of en-route capacity enhancement roadmap
APP10c	Final approach separation	approach	2011 – 2015	HIGH – part of terminal capacity enhancement roadmap

Table 7-7: ATM applications: introduction after 2010/widespread operational status by the end of 2015

7.2.3.3 This package of ATM applications delivers substantial levels of direct benefit including:

- significant reduction in controller workload via transfer of tactical controller/pilot dialogue to data link, delegation of controller tasks to pilots including, in some cases, separation responsibility and transfer of aircraft to conflict free routes. Note that the benefit analysis presented in Section 5.4 concluded that, in the en-route area, it is better to concentrate resources on ATM applications associated with airborne separation and self-separation rather than on provision of conflict-free trajectories. ATM application APP2d should therefore be given low priority in all areas except terminal.
- enhanced ground operations at a wider range of airports;
- improved flight profiles in regions with widespread availability of user preferred trajectories;
- safety benefits building on those facilitated by earlier ATM applications;
- potential ground infrastructure costs savings if ADS-B data is used to supplement or provide an alternative to existing radar data, particularly in the airport environment.

7.2.3.4 A further benefit is the support for confidence building leading to introduction of aircraft self-separation.

7.2.3.5 Realisation of the ATM applications in this package is supported by the following factors:

- significant confidence building via ATM applications implemented in previous phases.

7.2.3.6 The key risks to implementation, the mitigating actions and the key decisions are summarised in Table 7-8:

Risk	Mitigation	Key decision/action
High equipage requirements for air ground data link and for ADS-B	Mandate required equipage	Decide appropriate mandate and/or use of segregated airspace during transition period
Rate of change of control ATM application too fast to accommodate	Overall ATM applications includes greater separation responsibility for pilots and greater use of conflict free trajectory planning. To some extent	Consider whether there is a need to prioritise between increased use of separation ATM applications and conflict free trajectories.

	these ATM applications push in different directions (the first is more autonomy to aircraft, the second is an enhanced ground provided service which supports aircraft flexibility but keeps the ground system firmly in the loop). It may be necessary to prioritise between these developments (or it may not be necessary to do both)	
Significant change in separation responsibility	Successful implementation built on confidence gained with earlier related ATM applications and an early solution to providing an appropriate approvals process	Early identification of barriers to implementation of separation together with definition of a project programme to a) focus the monitoring of early ADS-B related ATM applications b) reduce the risks associated with transfer of responsibility c) provide a phased introduction of separation ATM applications starting with eg oceanic and building through regional implementation of eg clustering
Onboard integration of navigation and surveillance for safety critical applications noting that reliable performance of ADS-B systems now essential	Confidence building through earlier ATM applications	Carry out ongoing monitoring of ADS-B system performance to build confidence accuracy, integrity etc Design reversion procedures Address approvals issues and put in place a process for certification and approval

Table 7-8: Risks, mitigation, decisions and actions for ATM applications: widespread operational status by the end of 2015

7.2.4 Widespread operational status until after 2015

7.2.4.1 Table 7-9 lists the ATM applications which are unlikely to gain widespread operational status until after 2015 but which might be introduced in some areas before the end of 2015.

#	ATM application	Region of applicability	Timescale (intro. – wide usage)	Priority
APP11a	Cluster control in ATC managed airspace	en-route, transition	2013 – 2018	HIGH – part of en-route capacity enhancement roadmap
APP11b	Autonomous operations in FFAS	en-route, transition, remote en-route, oceanic	2013 – 2018	HIGH – part of en-route capacity enhancement roadmap

Table 7-9: ATM Applications: introduction before the end of 2015/widespread operational status until after 2015

7.3 Summary of roadmap for ATM applications which enhance capacity

7.3.1 Figure 7-1 illustrates the ATM application roadmap for ATM applications which contribute to enhancement of capacity in busy en-route areas. The figure is based on Table 5-14.

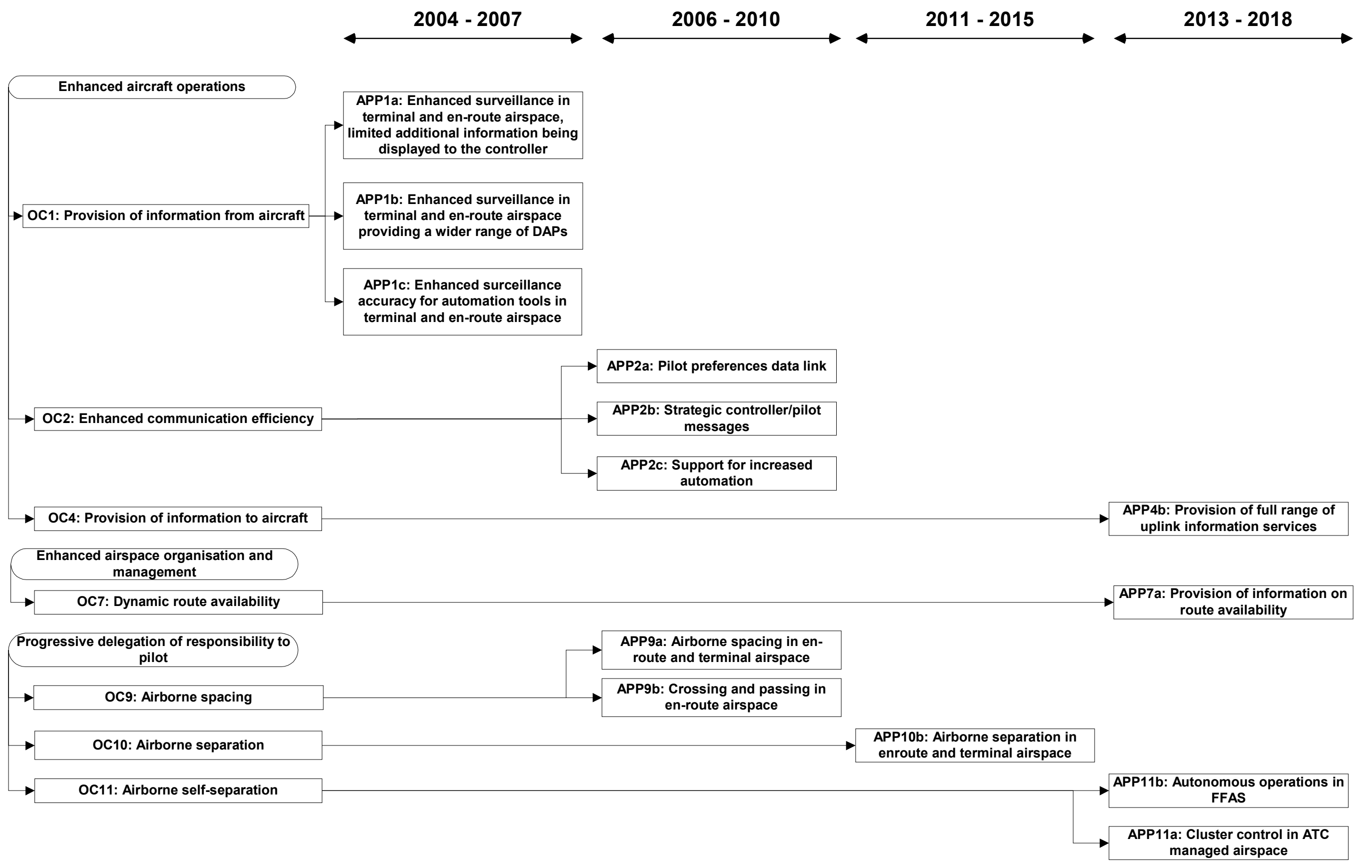


Figure 7-1: ATM application roadmap for capacity enhancement in busy en-route regions

7.3.2 Figure 7-2 illustrates the ATM application roadmap for ATM applications which contribute to enhancement of capacity in busy terminal and airport areas. The figure is based on Table 5-15.

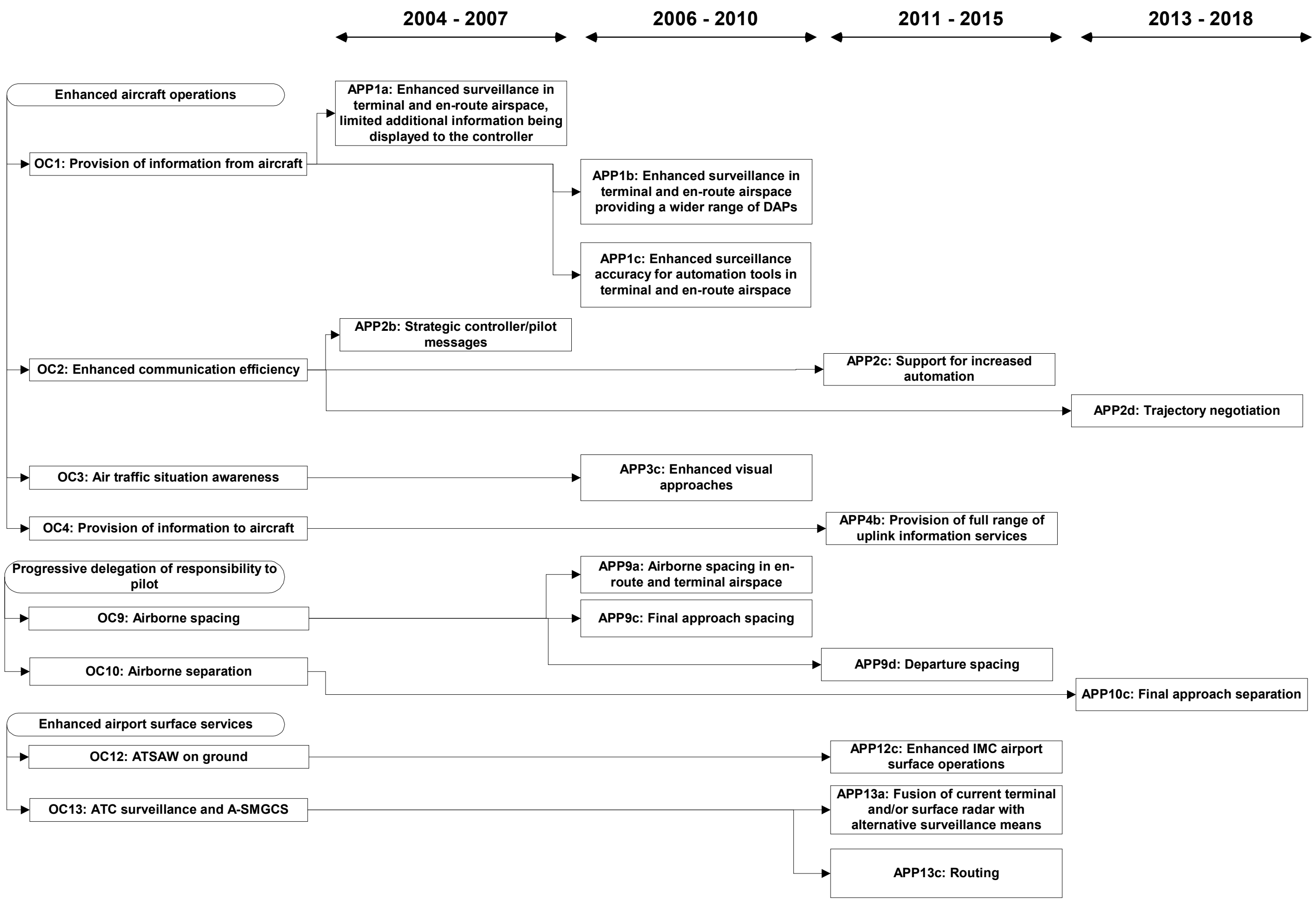


Figure 7-2: ATM Application roadmap for capacity enhancement in busy terminal and airport regions

8 Technical requirements

8.1 Introduction

8.1.1 This section presents the operational exchanges which are characteristic of each of the selected ATM applications. It then interprets the impact of those operational exchanges onto more technical communication exchanges. The resulting technical requirements are expressed as the decomposition of ATM applications into operational (communication) applications, data link services and data link applications. In this way - making as much use of other studies as possible - this study presents the operational requirements for one or more "communication pipelines", and the corresponding technical requirements.

8.1.2 The above decomposition approach is reflected by the following reference model used to specify the communication requirements, starting from the operational level of ATM applications.

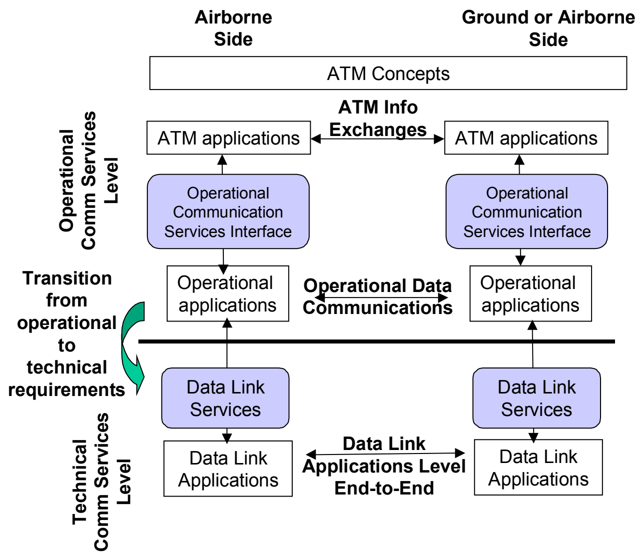


Figure 8-1: Reference Model for derivation of technical requirements

8.1.3 The reference model is a representation of airborne and ground co-operative ATM functions relying upon a global data link communication system. Two levels are presented:

- The upper level embraces the operational communications requirements. It presents the operational needs in terms of ATM information exchanges of ATM functions (interactions between ATM applications) and which operational data communication functions are required to support those exchanges (exchanges between operational applications). This provides a group of data communications functions, including data related to navigation, neighbouring traffic and general information. Essentially, each aircraft needs to get information from the outside and conversely, it shall provide information about itself.

- The lower level embraces the technical communication requirements .

8.1.4 Following the reference model, each ATM application of the concept is described according to the following characteristics, split into two different categories:

- The operational characteristics:
  - Region of applicability
  - Principle of use: the exchanges that may occur between pilot and ATCO or between pilots are described (pilot or controller read back are not mentioned)
  - Information exchanges between application participants (pilot, ATCO, airborne or ground system) ,i.e. content of the message
  - Operational constraints describing several operational requirements of the messages exchanged
- The interpretation of technical requirements:
  - The link with the operational characteristics is performed via the operational communication application bearing the ATM application, according to the operational constraints expressed;
  - Message characteristics: in terms of size of message, criticality (e.g. emergency, tactical, strategic), periodicity: it is the technical reflection of the operational constraints
  - Operational (communication) application: group of applications bearing the ATM applications among the six groups of application that have been identified and described hereafter.
  - D/L services and applications: bearing the operational applications; these services corresponds to data link services being specified by ODIAC; for common understanding purpose, ODIAC acronyms are used for already specified data link services; however, it is still to be checked whether ODIAC technical requirements cope with operational requirements presented in this document.

8.1.5 Six groups of operational application are identified:

- Pilot-ATCO dialog: this is a means of communication between two entities (the aircrew and the ATCO) for ATC service. It is based on message exchanges, including a set of clearance/information/request message elements, which correspond to voice phraseology employed by current ATC procedures, which could be extended to support further operational needs.
- Pilot-Pilot dialog: it is a communication exchange between the aircrew of two different aircraft, in-flight or eventually on the ground, for ATM service purpose (mainly co-ordination transactions).
- Automated provision of flight information services, i.e. “Ground-to-Pilot communication”: This operational application is based on the automatic sending of ground-available aircraft-environment information to a given aircraft. So the information sent is mainly data related to the environment of the aircraft and available on ground.

- Automated provision of aircraft information services, i.e. “Aircraft-to-Ground communication ”: It is mainly a surveillance technique for use by air traffic services in which aircraft automatically provide data derived from on-board position fixing and navigation systems. This operational application allows the ATCO to obtain position data and other information from equipped aircraft in a timely manner in accordance with their requirements.
- ATM automation: This application is based on the automatic exchange of ATM-related data between the airborne system (mainly the FMS) and the ground control system. It is based on message exchanges including principally trajectory and flight intent data.
- Air-Air surveillance: (also use by ground for enhance surveillance) This application relies on the periodic emission of data derived from on-board equipment in destination of other aircraft, generally in the vicinity, or ground.

8.1.6 The data Link Services description is as follows:

Initiation Service	
DLL: Data Link Logon Service	The DLL Service ensures all necessary technical and operational prerequisites for the exploitation of subsequently desired data link services.
Controller/ Pilot Data Link Communications (CPDLC) Services	
ACL: ATC Clearances and Information Service	The ACL Service involves both aircrew and controllers and specifies the Aircraft/C-ATSU message exchanges and procedures using Air/Ground data communications for operations within the European region for all flight phase, including ground movement, for the following: • Aircrew's report and clearance requests; • Controller's delivery of clearances, instructions and notification to aircraft • Support and system messages It further describes the rules for the combination of voice and data link communications and abnormal mode requirements and procedures.
ACM : ATC Communications Management Service	The ACM Service provides automated assistance to the Aircrew and Air Traffic Controllers for conducting the transfer of all ATC communications, both the voice channel and the data channel.
COTRAC: Common Trajectory Co-ordination	This service belongs, from a procedural point of view, to the "Clearance Delivery" series. Functionally it fits in the line of the CPDLC group of services. The purpose of COTRAC is to establish and agree trajectory contracts between aircrew and controllers in real time, using graphical interfaces, air and ground data communications and automation systems, in particular the FMS, by means of a structured negotiation method, in order to significantly enhance ATM capacity and flexibility.
DCL: Departure Clearance Service	The Departure Clearance (DCL) Service provides automated assistance for requesting and delivering departure information and clearance.
DSC: Downstream Clearances Service	Aircrew, in specific instances, needs to obtain clearances or information from ATSUs which may be responsible for control of the aircraft in the future, but are not yet in control of it. The Downstream Clearance (DSC) Service provides assistance for requesting and obtaining Downstream ATSU clearances or information, using air/ground data link.
Automatic Delivery of ATC Clearances Services	
DYNAV: Dynamic Route Availability Service	The DYNAV service automates the provision of route changes when alternative routings can be offered by an ATSU, even before the flight is under their control.
Automated Downlink of Airborne Parameters (ADAP) Services	
CAP: Controller Access Parameters Service	The CAP Service makes specific flight information available to the Controller by automatically extracting the relevant data from the airborne systems.

FLIPCY: Flight Plan Consistency Service	The FLIPCY Service automatically detects inconsistencies between the ATC used flight plan and the one activated in the aircraft's Flight Management System (FMS).
FLIPINT: (Extended FLIPCY for Trajectory Intent)	An extension of the FLIPCY service to accommodate the flight time and flight level components. Whilst the initial FLIPCY service is only two-dimensional, i.e. only the flight route projection is considered, extended FLIPCY is four-dimensional, it deals additionally with vertical profiles and estimated route timings.
PPD: Pilot Preferences Downlink Service	The PPD Service allows Aircrew in all phases of a flight to provide the Controller with information not available in the filed flight plan (e.g. maximum flight level) as well as requests for modification of some flight plan elements (e.g. requested flight level). It automates the provision to Controllers of selected Aircrew preferences even before the aircraft reaches their sector.
SAP: System Access Parameters	A relevant service in the procedural context of "Determination of Relative Positions", SAP belongs functionally to the ADAP services series. It aims at downlinking aircraft parameters to be used by several ground functions. SAP is an automatic system-to system service, without aircrew or controller involvement.
Data Link Flight Information Services (D-FIS)	
D-OTIS: Data Link Operational Terminal Information Service	The D-OTIS service provides Aircrew with automated assistance in requesting and delivering compiled meteorological and operational flight information derived from ATIS, METAR and NOTAMs / SNOWTAMs, specifically relevant to the departure, approach and landing flight phases.
D-RVR: Data Link Runway Visual Range	The D-RVR service provides the Aircrew with automated assistance in requesting and delivering the Instantaneous RVR.
D-SIGMET: Data Link SIGMET	This service, pertaining to the Data Link Flight Information Services group, provides automated assistance in requesting and delivering the Significant Meteorological Information (SIGMET) to aircrew. Controllers are not involved.

8.2 Derivation of technical requirements from operational applications characteristics

8.2.1 Note that this section has now been superseded by detailed technical requirements contained in the “Assessment Framework” document (P167D1040). The original text is retained as a record of work carried out within the study.

8.2.2 Operational constraints concern the exchanges of information and are characterised along the following axis for which a specific set of descriptors is associated. At this stage, the descriptors are only qualitative.

- Frequency: continuous (e.g. when associated with a surveillance objective, regular (e.g. clearances), sporadic (e.g. on event, few per flight), isolated (e.g. emergency message)
- Temporal coherence (e.g. round trip delay including human performances if human is involved in the exchanges of information, or one-way delay): the qualifier is related to the validity period of the exchanged information and the use of such information): High (i.e. information valid for few seconds), Medium (i.e. information valid for several minutes), Low (i.e. information valid during a portion of flight)
- Spatial coherence (i.e. coverage/range of the messages): geographically limited (i.e. related to the application scale), airport surface, entire TMA, ATCO own airspace, entire airspace
- Integrity: High, Medium, Low
- Availability: During all phases of flight, limited to the application duration (in both way can be either critical or non critical)
- Continuity: During all phases of flight, during the application duration

Only the more stringent axes are filled in, whereas the descriptor NE (Not Essential) is put for the others.

8.2.2 OC1: Provision of aircraft information

	APP1a	***APP1b***	***APP1c***	***APP1d***	**APP1e**
ATM applications	Enhanced surveillance in terminal and en-route airspace, limited information being displayed to the controller	Enhanced surveillance in terminal and en-route airspace providing a wider range of aircraft parameters	Enhanced surveillance accuracy for automation tools	Fusion of current radar and ADS-B surveillance	ATC surveillance using ADS-B
Region of applicability	En-route and Terminal	En-route and Terminal	En-route and Terminal	En-route and Terminal	En-route and Terminal
Principles of use; **Description of exchanges between protagonists (ATCO, pilot)**	Aircraft automatically provide the ground system with airborne information to be directly displayed to the ATCO	Aircraft automatically provide the ground system with airborne information to be directly displayed to the ATCO	Aircraft automatically provide the ground system with airborne information that are used by ground systems (e.g. MTCD, STCA, Trajectory prediction)	Aircraft broadcast information that are captured by the ground system and merge on the ground with radar data Broadcast from the ground to the air of the consolidated information	Aircraft broadcast information that are directly captured by the ground system or surrounding aircraft to be directly displayed to the controller or Pilot
Information exchanged	3 aircraft parameters (IAS, Magnetic Heading and vertical rate or selected altitude) sent to the ATCO in charge of the aircraft	Main CAP parameters (*Air Speed, Mach number, Magnetic Heading, Selected Altitude, Vertical Altitude, Wind Vector*) sent periodically to the ATCO in charge in the aircraft, and also to the ATCOs that could be in charge in the future	Aircraft information (a/c type, weight, heading, CAS, rate of climb and descent, selected CAS, selected heading, selected flight level) to the ATSUs for the ground automation	Aircraft information (state only, no intent) directly captured on the airborne bus from the sensors	Aircraft information (state only, no intent) directly captured on the airborne bus from the sensors
Operational constraints					
Frequency	Continuous (periodicity depending on airspace type and use of information)	Continuous (periodicity depending on airspace type and use of information)	Continuous (periodicity depending on airspace type and use of information)	Continuous (periodicity depending on airspace type and use of information)	Continuous (periodicity according to the airspace type)
Temporal coherence	High	High	High	High	High
Spatial coherence	Entire airspace	Entire airspace	Entire airspace	Entire airspace (but may be more relevant in terminal area where radar coverage performances are lower)	Entire airspace
Integrity	NE (e.g. Medium, but related to the actual operational use/need of such information)	NE (e.g. Medium, but related to the actual operational use/need of such information)	NE (e.g. Medium, but related to the actual operational use/need of such information by the tools)	NE (related to the actual operational use/need of such information by the tools, e.g. only as a back up or as sole mean)	High (sole mean of surveillance)

Availability	During all phases of flight (but non critical)	During all phases of flight (but non critical)	During all phases of flight (but non critical)	During all phases of flight (but criticality may be more according to the phase)	During all phases of flight (but highly critical)
Continuity	NE (During all phases of flight (but non critical))	NE (During all phases of flight (but non critical))	NE (During all phases of flight (but non critical))	NE	During all phases of flight
Operational (communication) applications	Automated provision of aircraft information services	Automated provision of aircraft information services	Automated provision of aircraft information services	Air-Air surveillance	Air-Air surveillance
Message characteristics	Short Periodic Range (TBD)	Short Periodic Range (TBD)	Short Periodic Range (TBD)	Short Periodic Range (TBD)	Short Periodic Range (TBD)
D/L services	CAP	CAP	SAP	“ADS-B” “TIS-B”	“ADS-B”
D/L applications	ADAP	ADAP	ADAP	ADS-B TIS-B	ADS-B

8.2.2.1 OC2: Enhanced communication efficiency

	APP2a	APP2b	APP2c	APP2d
ATM applications	Pilot Preferences Datalink	Strategic Controller/Pilot Messages	Support for Increased Automation	Trajectory Negotiation
Region of applicability	En-route, Terminal	En-route and Terminal	En-route and Terminal	En-route and Terminal
Principles of use; **Description of exchanges between protagonists (ATCO, pilot)**	Pilot informs the ATCO about its preferences about different parameters (e.g. Operating Climb Airspeed, Cruise Flight Level, Top of Descent…)	Current voice communications between pilots and controllers are made via D/L, apart from high-criticality tactical messages	Full range of new ATM services via D/L between the aircrew and the ATCO increasing automation between the ground system and the airborne system	4D and co-operative trajectory negotiation between the aircrew and the ATCO
Information exchanged	PPD parameters concerning aircraft preferred state (airspeed, approach speed, arrival speed…)	Request, sending and acknowledgement of clearances of strategic messages(and some tactical), departure clearances and downstream clearances	Flight Plan transfer initialisation messages	
			Trajectory transfer initialisation messages	
Operational constraints				
Frequency	Sporadic	Regular	Regular	Regular
Temporal coherence	Low	Medium	High/Medium	High/Medium
Spatial coherence	Entire airspace	ATCO own airspace	ATCO own airspace	ATCO own airspace
Integrity	NE (Medium)	NE	NE	NE
Availability	During all phases of flight	During all phases of flight	During all phases of flight	During all phases of flight
Continuity	During all phases of flight	During all phases of flight	During all phases of flight	During all phases of flight
Operational (communication) applications	Automated provision of aircraft information services	Pilot-ATCO dialog	Pilot-ATCO dialog	Pilot-ATCO dialog
		ATM automation	ATM automation	ATM automation
Message characteristics	Short Periodic Peer-to-Peer	Short Regular basis Peer-to-Peer	Short Regular basis Peer-to-Peer	Short Regular basis Peer-to-Peer
			Long Punctual Peer-to-Peer	
D/L services	PPD	DLIC, ACM, ACL, DSC	Enhanced ACL	Enhanced ACL
		FLIPCY	FLIPCY	FLIPCY + FLIPINT + COTRAC
D/L Applications	ADS-C	CPDLC	CPDLC	CPDLC
		ADS-C	ADS-C	ADS-C

8.2.3 OC3: Airborne Situation Awareness

	APP3a	APP3b	APP3c	APP3d
ATM applications	Enhanced visual acquisition (EVA) in remote and oceanic airspace	Enhanced (extended) visual acquisition (EVA) in terminal airspace	Enhanced visual approaches	Traffic situational awareness in en-route airspace
Region of applicability	Remote and Oceanic airspace	Terminal	Terminal region	En-route
Principles of use; **Description of exchanges between protagonists (ATCO, pilot)**	- The CDTI displays the surrounding traffic based on air-air surveillance information - ATCO designates a traffic to the pilot - Pilot acknowledges traffic acquisition using the CDTI and visual scan outside the cockpit	- The CDTI displays the surrounding traffic based on ground-air and air-air surveillance information - ATCO designates a traffic to pilot - Pilot confirms the traffic acquisition using the CDTI and visual scan outside the cockpit	- ATCO designates a traffic to pilot - Pilot acknowledges traffic acquisition - ATCO clears the pilot to perform visual approach - Pilot is provided with surrounding traffic information (CDTI)	Pilot is provided with surrounding traffic information
Information exchanged	- Traffic ident (e.g. call-sign) from the ATCO to the Aircrew - Confirmation by the Aircrew	- Traffic ident (e.g. call-sign) from the ATCO to the Aircrew - Confirmation by the Aircrew	- Traffic ident (e.g. call-sign) - Ack - ATCO clearance	N/A
	A/c-A/c information(without intent)	A/c-A/c information(without intent)	A/c-A/c information(without intent)	A/c-A/c information(without intent)
Operational constraints				
Frequency	Sporadic			
Temporal coherence	High			
Spatial coherence	ATCO own airspace			
Integrity	TBD			
Availability	During all phases of flight (but more relevant in approach phases)			
Continuity	NE	NE	NE	NE
Operational constraints (for air-air surveillance)				
Frequency	Continuous			
Temporal coherence	High			
Spatial coherence	Geographically limited			
Integrity	High			
Availability	NE (During all phases of flight (but more relevant in approach phases))			
Continuity	NE (During all phases of flight (but more relevant in approach phases))			
Operational (communication) applications	- ATSAW Pilot/ATCO dialog - Voice (initial implementation)	- ATSAW Pilot/ATCO dialog - Voice (initial implementation)	- ATSAW Pilot/ATCO dialog - Voice (initial implementation)	N/A

	Air-air surveillance	Air-air surveillance	Air-air surveillance	Air-air surveillance
Message characteristics	Short Punctual Tactical messages	Short Punctual Tactical messages	Short Punctual Tactical messages	
	Short Periodic (every TBS) Range	Short Periodic (every TBS) Range	Short Periodic (every TBS) Range	Short Periodic (every TBS) Range
D/L services	*Enhanced ACL (ATSAW extension?)*	*Enhanced ACL (ATSAW extension?)*	*Enhanced ACL (ATSAW extension?)*	
	“ADS-B”	“ADS-B/TIS-B”	“ADS-B/TIS-B”	“ADS-B/TIS-B”
D/L applications	*Enhanced CPDLC*	*Enhanced CPDLC*	*Enhanced CPDLC*	
	ADS-B	ADS-B/TIS-B	ADS-B/TIS-B	ADS-B/TIS-B

8.2.4 OC4: Provision of information to aircraft

	APP4a	APP4b
ATM applications	Provision of terminal (automatic terminal information service, meteorological report) and runaway information	Provision of full range of uplink information services
Region of applicability	Terminal and En-route	Terminal and En-route
Principles of use; **Description of exchanges between protagonists (ATCO, pilot)**	Transmission from the ground to the aircraft of operational flight information (automatic terminal information service, meteorological report and runaway visual range information)	Transmission from the ground to the aircraft of flight-operation-related and meteorological information (notice of important information to airmen, snow alert information, significant weather information and common trajectory co-ordination)
Information exchanged	*- Information request* *- acknowledgement message sent from the aircraft to the ground*	*- Information request* *- acknowledgement*
	Delivery of the operational flight information from the ground to the aircraft	Delivery of the long operational flight information from the ground to the aircraft
Operational constraints		
Frequency	Continuous (if broadcast) or Sporadic (if requested by pilot)	Continuous (if broadcast) or Sporadic (if requested by pilot)
Temporal coherence	Low	Low
Spatial coherence	Depend on message type (e.g. Entire TMA or entire airspace)	Depend on message type (e.g. Entire TMA or entire airspace)
Integrity	NE	NE
Availability	During all phases of flight (but more relevant in departure of approach phases)	During all phases of flight (but more relevant in departure of approach phases)
Continuity	During all phases of flight	During all phases of flight
Operational (communication) applications	Automated provision of flight information services	Automated provision of flight information services
Message characteristics	Short Punctual Medium quality Peer-to-peer	Short Punctual Medium quality Peer-to-peer
	Long Punctual Medium quality Peer-to-peer	Long Punctual Medium quality Peer-to-peer
D/L services	D-ATIS, METAR D-RVR	NOTAM, SNOWTAM, D-SIGMET
D/L applications	D-FIS	D-FIS

8.2.5 OC7: Dynamic route availability

	APP7a
ATM applications	Provision of information on route availability
Region of applicability	All phases of flight.
Principles of use; **Description of exchanges between protagonists (ATCO, pilot)**	Ground informs the pilot on available routes (based on Flight Plan Info, the ATSU's Flight Data Processing generates route change proposals) Aircrew accepts or rejects the proposal
Information exchanged	- Proposed routing from ATSU - Wilco or Reject from Aircrew
Operational constraints	
Frequency	Sporadic
Temporal coherence	Medium
Spatial coherence	ATCO own airspace
Integrity	Maximum
Availability	Limited to the application duration
Continuity	NE
Operational (communication) applications	Pilot-ATCO dialog Automatic provision of flight information services
Message characteristics	Long In first phase of flight Point-to-Point
D/L services	DYNAV (ACL service to provide “Proposed route”)
D/L applications	ADS-C (CPDLC)

8.2.6 OC9: Airborne Spacing

<table>
<tr><th></th><th>APP9a</th><th>APP9b</th><th>APP9c</th><th>APP9d</th></tr>
<tr><td>ATM applications</td><td>Airborne spacing in en-route and terminal airspace</td><td>Crossing and passing in en-route airspace</td><td>Final approach spacing</td><td>Departure spacing</td></tr>
<tr><td>Region of applicability</td><td>En-route and terminal region</td><td>En-route</td><td>Terminal region</td><td>Terminal region</td></tr>
<tr><td rowspan="3">Principles of use;

Description of exchanges between protagonists (ATCO, pilot)</td><td colspan="4">These ATM applications are based on the same communication principles of use. There are three phases: the application initialisation (target identification and instructions), execution and termination.
It is important to underline that, during all these procedures, the ATCO remains responsible for all the aircraft of its area of control.

- Pilot is provided with surrounding traffic information via surveillance information; this data is displayed on the CDTI, to allow the identification of the future target aircraft.

- ATCO verifies that the conditions of applicability for spacing application are respected and, if necessary, sends tactical instructions to adapt situation (aircraft respective relative speeds, headings…)
- ATCO then designates the target aircraft to the pilot
- Pilot acknowledges target acquisition with the help of the CDTI to identify the target.</td></tr>
<tr><td>- ATCO sends a spacing instruction to the pilot to perform the spacing (e.g. “Remain behind” instruction)
- Pilot informs the ATCO that the spacing is possible to maintain
- Pilot reports to the ATCO relevant information related to the spacing instruction (e.g. spacing distance reached…)</td><td>- ATCO sends a crossing instruction to the pilot (e.g.: heading to deviate from its trajectory and a track resume instruction)
- Pilot informs the ATCO that the spacing is possible to maintain
- Pilot reports to the ATCO relevant information related to the crossing and passing instruction (e.g. effective heading, clear of traffic)</td><td colspan="2">- ATCO sends the spacing instruction to the pilot: spacing value (time or distance) e.g.:“keeping in NAV TRAIL 90 sec to target a/c”
- Pilot informs the ATCO that the spacing is possible to maintain
- Pilot eventually reports to the ATCO relevant information related to TMA spacing</td></tr>
<tr><td colspan="4">- Either the pilot or the ATCO can terminate the spacing (with an explicit message in the initial instruction, or implicitly if an end parameter is passed, notably if the aircraft comes too close to its target)</td></tr>
<tr><td rowspan="2">Information exchanged</td><td colspan="4">- Traffic identification (e.g. call-sign)
- Confirmation
- Spacing instruction: heading, speed…</td></tr>
<tr><td colspan="4">A/C-A/C information(without intent)</td></tr>
<tr><td>Operational constraints</td><td colspan="2"></td><td></td><td></td></tr>
<tr><td>Frequency</td><td colspan="2">Sporadic</td><td>Sporadic</td><td>Sporadic</td></tr>
<tr><td>Temporal coherence</td><td colspan="2">High/Medium</td><td>High/Medium</td><td>High/Medium</td></tr>
<tr><td>Spatial coherence</td><td colspan="2">ATCO own airspace</td><td>ATCO own airspace/entire TMA</td><td>ATCO own airspace/entire TMA</td></tr>
<tr><td>Integrity</td><td colspan="2">TBD</td><td>TBD</td><td>TBD</td></tr>
<tr><td>Availability</td><td colspan="2">During all phases of flight</td><td>During arrival phases</td><td>During departure phases</td></tr>
<tr><td>Continuity</td><td colspan="2">During the application duration</td><td>During the application duration</td><td>During the application duration</td></tr>
<tr><td>Aircraft/Aircraft exchange of info</td><td colspan="2"></td><td></td><td></td></tr>
<tr><td>Frequency</td><td colspan="2">Continuous</td><td>Continous</td><td>Continuous</td></tr>
</table>

Temporal coherence	High	High	High
Spatial coherence	Geographically limited	Geographically limited	Geographically limited
Integrity	High	High	High
Availability	During all phases of flight	During arrival phases	During departure phases
Continuity	During the application duration	During the application duration	During the application duration
Operational (communication) applications	- Spacing Pilot/ATCO dialog - Voice (initial implementation)	- Spacing Pilot/ATCO dialog - Voice (initial implementation)	
	Air-air surveillance (without intent)		
Message characteristics	Short Punctual Tactical mess	Short Punctual Tactical mess	
	Short Periodic Range (to be completed)	Short Periodic Range (to be completed)	
D/L services	*Enhanced ACL*	*Enhanced ACL*	
	“ADS-B/TIS-B”	“ADS-B/TIS-B”	
D/L Application	- *Enhanced CPDLC*	- *Enhanced CPDLC*	
	ADS-B/TIS-B	ADS-B/TIS-B	

8.2.7 OC10: Airborne separation

	APP10a	APP10b	APP10c
ATM applications	Airborne separation in oceanic and remote airspace	Airborne separation in en-route and terminal airspace	Final approach separation
Region of applicability	Oceanic and remote non-radar airspace	En-route and terminal airspace	Terminal regions
Principles of use; **Description of exchanges between protagonists (ATCO, pilot)**	These ATM applications are based on the same principles of use from a communication point of view. - Pilot is provided with surrounding traffic information via surveillance information; this data is displayed on the CDTI (to allow the identification of the future target aircraft). - ATCO designates a target aircraft to the pilot - Pilot confirms or rejects target identification. - ATCO sends a separation clearance (instruction) to the pilot to perform the application. - The pilot accepts or rejects the instruction. - Pilot reports to the ATCO relevant information (e.g. distance reached). - Either ATCO or the pilot can end the application.		
Information exchanged	- Traffic ident (e.g. call-sign) - Confirmation - Separation clearance (e.g. end of delegation, separation objectives if any but normally not necessary, other TBD)		
	A/c-A/c information (with intent)		
Operational requirements and constraints			
Frequency	Sporadic	Sporadic	Sporadic
Temporal coherence	Medium	Medium	Medium
Spatial coherence	Geographically limited	Geographically limited	Geographically limited
Integrity	High (very critical)	High (very critical)	High (very critical)
Availability	During all phases of flight	During all phases of flight	During approach phases
Continuity	During the application duration	During the application duration	During the application duration
Aircraft/Aircraft exchange of info			
Frequency	Continuous	Continuous	Continuous
Temporal coherence	High	High	High
Spatial coherence	Geographically limited	Geographically limited	Geographically limited
Integrity	High (very critical)	High (very critical)	High (very critical)
Availability	During all phases of flight (en-route)	During all phases of flight	During approach phases
Continuity	During the application duration	During the application duration	During the application duration
Operational (communication) applications	- Separation Pilot/ATCO dialog - Voice (initial implementation)		
	Air-air surveillance (with intent)		

Message characteristics	Short Punctual Tactical messages		
	Short Periodic (every TBS)		
D/L services	*Enhanced ACL*	*Enhanced ACL*	*Enhanced ALC*
	"ADS-B"	"ADS-B/TIS-B"	"ADS-B/TIS-B"
D/L applications	*Enhanced CPDLC*	*Enhanced CPDLC*	*Enhanced CPDLC*
	ADS-B	ADS-B/TIS-B	ADS-B/TIS-B

8.2.8 OC11: Autonomous aircraft application

	APP11a	APP11b
ATM applications	Cluster control in ATC managed airspace	Autonomous operations in FFAS
Region of applicability	Oceanic, en-route and remote non-radar airspace	FFAS
Principles of use;	- Pilot is provided with surrounding traffic information (state + trajectory intent);	
Description of exchanges between protagonists (ATCO, pilot)	- ATCO is responsible for the identification for the Cluster Control opportunity between two or more suitable equipped aircraft. - One of these aircraft is designed as reference. It receives a clearance from the ATCO. - ATCO sets up the cluster by providing instructions if necessary. - Each involved flight crew confirms that the other aircraft have been identified. - The ATCO transfers the responsibility for maintaining separation to the flight crews by providing a Cluster Control clearance. - Flight crews maintain separation according to the parameters provided in the controller clearance. Within the cluster, they co-ordinate themselves using tactical and strategic clearances. - The controller is still responsible to monitor the separation within the cluster and with aircraft outside the cluster.	- Pilot and ATCO negotiate the transition issues (e.g. between FFAS/MAS, pilot request, or ATCO clearance to enter, leave MAS and FFAS); - Aircraft perform conflict detection on-board; - Conflicting aircraft automatically exchange information relative to Conflict Detection and Resolution (CD&R) (e.g. exchange of priority for a priority rule based CD&R algorithm). Other algorithms than CD&R can also be used with different parameters exchanged; - In case of abnormal CD&R, possible necessity exchange additional information.
Information exchanged	Cluster composition information Set-up instructions and clearances	CD&R information (e.g. priority) Transition information (e.g. time, point)
	A/c-A/c information (state + intent) Cluster co-ordination information	A/c-A/c information (state + intent); Exchange of Conflict information
Operational requirements and constraints		
Frequency	Sporadic	Sporadic (may depend on the average number of conflicts that may be encountered during the flight)
Temporal coherence	High/medium	High
Spatial coherence	Geographically limited	Geographically limited
Integrity	High	High
Availability	TBD	During phase of flight within FFAS
Continuity	During application duration	During application duration (i.e. within FFAS or during transition periods)
Aircraft/Aircraft exchange of info		
Frequency	Continuous	Continuous
Temporal coherence	High	High
Spatial coherence	Geographically limited	Geographically limited
Integrity	TBD	High

Availability	TBD	During phase of flight within FFAS
Continuity	TBD	During application duration (i.e. within FFAS)
Message characteristics	Punctual Short	- Pilot/Pilot: Short Punctual (to be differentiated with on event) On event (e.g. emission of a new conflict free trajectory) - ATCO/Pilot: Idem
	Short message (required intent)	- Short (state) and Long (intent) messages - Different periodicity's according to the message content
Operational (communication) applications	- Cluster ATCO-Pilot dialog - Pilot/Pilot dialog	- AUTOPS Pilot/Pilot dialog - AUTOPS Pilot/ATCO dialog
	Air-air surveillance	Air-air surveillance
D/L services	- *Enhanced ACL* - *Pilot-pilot dialog*	- *Enhanced ACL* - *Pilot-pilot dialog*
	"ADS-B"	"ADS-B"
D/L applications	- *Enhanced CPDLC* - *Pilot-pilot dialog*	- *Enhanced CPDLC* - *Pilot-pilot dialog*
	ADS-B	ADS-B

8.2.9 OC12: ATSAW on ground

	APP12a	APP12b	APP12c
ATM applications	Surface enhanced visual acquisition	Runway and final approach occupancy awareness	Enhanced IMC airport surface operations
Region of applicability	Ground	Terminal and ground	Terminal and ground
Principles of use; **Description of exchanges between protagonists (ATCO, pilot)**	An airport map is displayed on a CDTI. Pilot is provided with a map of the airport. Thus, the flight crew's assessment of surface target position, direction and speed on the airport surface is supplemented.	The CDTI displays the surrounding traffic based on ground-air and air-air surveillance information Pilot confirms the traffic acquisition using the CDTI and visual scan outside the cockpit.	An airport map is displayed on a CDTI. This is similar to APP12a, but enhances operations in reduced visibility supporting, in particular, landing and take-off and possibly taxi operations.
Information exchanged	Info from ground to provide surface picture.	Traffic ident (e.g. call-sign) from the ATCO to the flight crew. Confirmation by the flight crew. A/c – a/c information (without ident)	Info from ground to provide surface picture. Traffic ident (e.g. callsign) from the ATCO to the flight crew. Confirmation by the flight crew. A/c – a/c information (without ident)
Operational constraints			
Frequency	Continuous	Continuous	Continuous
Temporal coherence	High	High	High
Spatial coherence	Airport surface	ATCO own airspace	ATCO own airspace
Integrity	High	High	High
Availability	During ground phase	During arrival and departure phases, ground phase	During arrival and departure phases, ground phase
Continuity	During the application duration	During the application duration	During the application duration
Operational (communication) applications	Ground-to-pilot communication	Ground-to-pilot communication, air-air surveillance	Ground-to-pilot communication, air-air surveillance
Message characteristics	Long Broadcast Range (TBD)	Long Broadcast Range (TBD)	Long Broadcast Range (TBD)
D/L services	- ATSAW	- ATSAW	- ATSAW
D/L applications	ADS-B / TIS-B	ADS-B / TIS-B	ADS-B / TIS-B

8.2.10 OC13: ATC Surveillance and A-SMGCS

	APP13a	APP13b	APP13c
ATM applications	Fusion of current terminal and/or surface radar with other surveillance means	ATC surveillance using ADS-B at airport	Routing
Region of applicability	Ground and terminal	Ground and terminal	Ground
Principles of use;	ATCO are provided with alternative/enhanced traffic information, provides enhanced surveillance accuracy.	ATCO are provided with pseudo radar separation standards at airports without radar coverage.	Routing information provided to the pilots (e.g. taxi clearances on the airport surface).
Description of exchanges between protagonists (ATCO, pilot)	Aircraft broadcast information that is captured by the ground system and merged on the ground with radar data.	Aircraft broadcast information that is captured by a ground system.	In manual mode, a route will be transmitted by the controller to the pilot. In automatic mode: automatic clearance delivery feeding pilots (e.g. routes directly sent to aircrew). Real time change of the route or destination.
Information exchanged	Aircraft information (state only, no intent)	Aircraft information (state only, no intent)	Route information
Operational constraints			
Frequency	Continuous	Continuous	Sporadic
Temporal coherence	High	High	High
Spatial coherence	Entire TMA/ground/ATCO own airspace	Entire TMA/ground/ATCO own airspace	Entire TMA/ground/ATCO own airspace
Integrity	NE (dependent on the actual operational use of the information, e.g. as backup or as a sole mean)	High (sole mean of surveillance)	Medium
Availability	During arrival and departure phases, ground phase	During arrival and departure phases, ground phase	During arrival and departure phases, ground phase
Continuity	During the application duration	During the application duration	During the application duration
Operational (communication) applications	ATM automation, aircraft-to-ground communication	ATM automation, aircraft-to-ground communication	Ground-to-pilot communication
Message characteristics	Long Broadcast Range (TBD)	Long Broadcast Range (TBD)	Long Point-to-point Range (TBD)
D/L services	"ADS-B"	"ADS-B"	"ADS-B"
D/L applications	ADS-B	ADS-B	ADS-B

8.2.11 OC14: ATS in oceanic/remote area

	APP14a	APP14b
ATM applications	Basic surveillance infrastructure via ADS-B in remote regions	ATS in oceanic/remote areas
Region of applicability	Remote areas	Remote and Oceanic areas
Principles of use; **Description of exchanges between protagonists (ATCO, pilot)**	Information is transmitted from aircraft to ground (or air to air) without the involvement of aircrew or controllers.	Positions reports will be sent to ground periodically, at waypoints or on demand Data Communication between controller and pilot.
Information exchanged	Info to ground to provide surveillance picture (e.g., 3D aircraft position)	Regular position reports
		Clearance delivery
Operational constraints		
Frequency	Continuous	Continuous Regular
Temporal coherence	High	High
Spatial coherence	Entire Airspace	Entire Airspace
Integrity	High	High
Availability	During all phases of flights	During all phases of flights
Continuity	During all phases of flight	During all phases of flight
Operational (communication) applications	Automated provision of aircraft information services Air-Air surveillance	Pilot-ATCO dialog Automatic provision of flight information services Automatic provision of aircraft performance services
Message characteristics	Short Periodic Broadcast	Short Periodic Point-to-Point
D/L services	ATSAW	ATSAW Enhanced ACL (DSC, DCL)??
D/L applications	ADS-B	ADS-C CPDLC

8.3 Detailed technical requirements

8.3.1 Detailed technical requirements are defined in document P167D1040: Assessment Framework.

A Acronyms and references

A.1 Acronyms

A-SMGCS	Advanced Surface Movement Guidance and Control Systems
ACARS	Aircraft Communication Addressing and Reporting System
ACC	Area Control Centre
ACL	ATC Clearance and Information (Service)
ACM	ATC Communications Management (Service)
ADAP	Automated Downlink of Airborne Parameters
ADS	Automatic Dependent Surveillance
ADS-B	ADS Broadcast
ADS-C	ADS Contract
AFAS	Aircraft in the Future ATM System
AGC	Air/ Ground Co-operative ATS (EATMP Programme)
AIRSAW	Airborne Situation(al) Awareness
AIS	Aeronautical Information Services
AMAN	Arrivals Manager
AMC	Airspace Management Cell
AOC	Airline Operational Communications
ARTAS	Air Traffic Management Surveillance Tracker and Server System
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control (Service) (Unit)
ATCO	Air Traffic Control Officer (Controller)
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
ATSAW	Air Traffic Situation(al) Awareness
AUTOPS	Autonomous Flight Operations
CAP	Controller Access Parameters (Service)
CBA	Cost Benefit Analysis
CDTI	Cockpit Display of Traffic Information
CDM	Collaborative Decision Making
CFMU	Central Flow Management Unit

CMU	Communications Management Unit
CNS/ATM	Communications, Navigation, Surveillance/ Air Traffic Management
COOPATS	Co-operative ATS (ATM application)
COSEP	Co-operative Separation Assurance
COTRAC	Common Trajectory Co-ordination (Service)
CTAS	Center – TRACON Automation System
CPDLC	Controller/ Pilot Data Link Communications (Services)
CWP	Controller Working Position
D-FIS	Data Link Flight Information (Services)
D-OTIS	Data Link Operational Terminal Information (Service)
D-RVR	Data Link Runway Visual Range (Service)
D-SIGMET	Data Link Significant Meteorological Information (Service)
DADI	Datalinking of Aircraft – Dervived Information
DAP	Downlink Aircraft Parameters
DCL	Departure Clearance (Service)
DLIC	Datalink Initiation Capability
DMAN	Departure Manager
DSC	Downstream Clearances (Service)
DYNAV	Dynamic Route Availability (Service
E-S&A	Enhanced See and Avoid (
E-TIBA	Enhanced Traffic Information Broadcast
E-ATSAW	Enhanced ATSAW
EASA	European Aviation Safety Authority
EATMP	European Air Traffic Management Programme
ECAC	European Civil Aviation Conference
EUROCAE	European Organisation for Civil Aviation Equipment manufacturers
EVA	Enhanced visual acquisition
FAA	Federal Aviation Administration
FANS	Future Air Navigation Systems (ICAO ATM application)
FANS-1/A	Future Air Navigation System, an operational data link package initially developed for the South Pacific; 1 corresponds to Boeing implementation; A corresponds to Airbus implementation
FDP	Flight Data Processing
FIR	Flight Information Region

FIS	Flight Information Services
FFAS	Free Flight Airspace
FFM	Free Flight Mode
FIS	Flight Information Services
FLIPCY	Flight Plan Consistency (Service)
FMS	Flight Management System
FREER	Free Route Experimental Encounter Resolution
FUA	Flexible Use of Airspace
GBAS	Ground Based Augmentation System
HMI	Human Machine Interface
ICAO	International Civil Aviation Organisation
ITC	In-Trail Climb
ITD	In-Trail Descent
JAA	Joint Aviation Authority
JAFTI	JURG ADS Fast Track Initiative
JURG	Joint User Requirements Group
MA-AFAS	More Autonomous Aircraft in the Future ATM System
MAS	Managed Airspace
MASPS	Minimum Aviation System Performance Specification
MET	Meteorological
METAR	Meteorological Report
MFF	Mediterranean Free Flight
MOPS	Minimum Operational Performance Specification
MSAW	Minimum Safe Altitude Warning
MTCD	Medium Term Conflict Detection
NOTAM	Notification to Air Men
NUP	NEAN update programme
OCD	Operational Concept Document
OCM	Oceanic Clearance Message
ODIAC	AGC Focus Group
OFIS	Operation Flight Information Service
OHA	Operational Hazard Analysis
OSED	Operational Service and Environment Description

PETAL	Preliminary EUROCONTROL Test of Air/Ground data link
PDC	Pre-departure clearance
PO-ASAS	Airborne Separation Assurance System
PPD	Pilot Preferences Downlink (Service)
R/T	Radio Telephony
RDP	Radar Data Processing
SAP	System Access Parameters (Service)
SIGMET	Significant Meteorological Information
SNOWTAMS	Snow Alert
SSR	Secondary Surveillance Radar
STARS	Standard Arrivals
STCA	Short Term Conflict Alert
TIS	Traffic Information Service
TIS-B	TIS-broadcast
TMA	Terminal Manoeuvring Area
VFR	Visual Flying Rules
VMC	Visual Meteorological Conditions

A.2 References

A.2.1 The Study Team has assembled a bibliography, from which, the following references, which are used in this document, have been extracted.

Ref no.	Title	Publisher	Date
20	LINK 2000+ Programme Master Plan, Version 0.94	Eurocontrol	30 July 2001
22	Concept of Operations Mode S in Europe (Mode S CONOPS), SUR.ET2.ST02.1000-CNP-01-00	Eurocontrol	28 Nov 1996
38	An analysis of the costs and benefits of ADS based on operational case studies - Results of Stage 1 ADS Programme CBA, Edition 0.4	Eurocontrol	September 2001
39	Towards Cooperative ATS - The COOPATS Concept, AGC/MOD/DEL01, Edition 1.0	Eurocontrol	18 June 2001
97	Operating Concept of the Mobile Aviation Communication Infrastructure Supporting ATM beyond 2015 – Deliverable D1	Eurocontrol	Draft version of Feb 02
98	NUP Phase 1 Final Report	NUP project team	draft version used for ADS Symposium 12 to 14th March 2002
107	Eurocontrol ADS Web site: http://www.eurocontrol.int/projects/eatchip/ads/default.htm		
108	MFF project: public documentation		
109	NUP project: public documentation		

Ref no.	Title	Publisher	Date
	http://www.avions.aerospatiale.fr/afas/index.html		
110	MA-AFAS project: public documentation http://www.ma-afas.com/		
112	Eurocontrol CARE/ASAS documentation http://www.eurocontrol.int/care/index.html		
113	EEC FREER project documentation http://www.eurocontrol.fr/projects/freer/		
115	AEA/IATA ATM-CNS Joint User Requirements Group (JURG) ADS Fast Track Initiative JAFTI	JURG	Version 1.2 15 May 2002
116	Proposal for a first package GS/AS applications	Eurocontrol – CARE/ASAS Activity 5 – version 1.2	14 May 2002
118	Eurocontrol MACONDO project	Eurocontrol	
119	SAMS (SMGCS Airport Movement Simulator) - Final Report for Publication (Deliverable D5.5) http://europa.eu.int/comm/transport/extra/final_reports/air/SAMS.pdf	European Commission	
120	ATOPS (A-SMGCS Testing of Operational procedures by Simulation) Final Report for Publication http://europa.eu.int/comm/transport/extra/final_reports/air/atops.pdf	European Commission	
121	OPTAS A (OPTimisation of Airport Systems, Part A) http://europa.eu.int/comm/transport/extra/final_reports/air/OPTAS_A.pdf	European Commission	
122	OPTAS B (OPTimisation of Airport Systems, Part B) http://europa.eu.int/comm/transport/extra/final_reports/air/OPTAS_B.pdf	European Commission	
123	VISION (improVed aIrport A-SMGCS by integrated multisensor data fuSION)	European Commission	
124	DEFAMM : Development of demonstration Facilities for Airport Movements guidance control & Management	European Commission	
125	AIRPORT-G : Airport Integrated Research & development Project for Operational Regulation of Traffic-Guidance	European Commission	
126	ATHOS : Airport Tower Harmonized cOntroller System	European Commission	
127	TARMAC: Taxi And Ramp Management And Control	European Commission	
128	A - SMGCS Ground Control Assistance Tools for Europe (AGATE)	European Commission	
129	Information requirements for low-visibility **taxi operations: What pilots say** http://human-factors.arc.nasa.gov/ihi/tnasa/pubs/Andre_AvPsyc95_jumpseat.pdf	NASA	
130	OPTIMIZING AIRPORT SURFACE OPERATIONS USING DATALINK AND THE TAXIWAY NAVIGATION AND SITUATION AWARENESS (T-NASA) DISPLAY SUITE http://human-factors.arc.nasa.gov/ihi/tnasa/pubs/Hooey_hfesposter_00.pdf	NASA	

Ref no.	Title	Publisher	Date
131	A comparative Study of ADS-B Link Costs by the FAA and Eurocontrol, Anne Yablonski Rurup et al, ADS-B Workshop, Rome,	FAA	March 2002
132	ADS-B Data Link Analysis: UAT in the 2015 Core European Scenario, Helios Technology, UAT-WP-11-22 (RTCA SC-186, WG-5).	RTCA	February 2002
133	AEA/IATA ATM-CNS Joint User Group (JURG) ADS Fast Track Initiative (JAFTI) Deliverables Document, Version 1.1,	AEA/IATA	April 2002.
134	ATC Simulation Report: Delegated Airborne Separation during Approach and Climb Out. NUP	SATSA	May 2000,
135	Comments on cost basis for comparison of alternative ADS-B datalink, Stephen Heppe (ADSI), AMCP/WGW Flimsy 1	AMCP	May 2002
136	DO181C, Minimum Operational Performance Standards for ATCRBS/Mode S Airborne Equipment,	RTCA,	July 2001.
137	Feasibility of finding UAT frequencies in the ARNS-Band 960-1215 MHz within the core area of Europe, , AMCP WGW/WP21,	DFS	May 2002.
138	FIS-B Service Description, NUP, Version 1.0,	NUP	February 2002.
139	MASPS for Traffic Information Service - Broadcast, RTCA Paper No. 095-02/SC-186-193.	RTCA	March 2002
140	MASPS for Airborne Separation Assurance, RTCA SC186 WG4, DRAFT 0.2.5C,	RTCA	September 2001
141	MASPS for Automatic Dependent Surveillance - Broadcast, RTCA DO-242A, Draft 1,	RTCA	March 2002
142	MASPS for Flight Information Service – Broadcast, RTCA D0-267,	RTCA	March 2001
144	Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance Broadcast (ADS-B), RTCA Paper No. 098-02/SC186-195 Prepared by: SC-186, WG-5, Drafted for Plenary Review:	RTCA	May 8, 2002
145	OpEval Final Report, OpEval Coordination Group (OCG),	FAA	April 10 2000.
146	OpEval-2 Final Report, OpEval Coordination Group (OCG),	FAA	August 13 2001.
147	Results on the utilisation of the frequencies 978 and 979 MHz in Europe, Eurocontrol, UAT-WP-5-15 (RTCA SC-186 WG-5).	RTCA	March 2002
148	Safe Flight 21 – CBA Basis of Estimates,	FAA	April 2001,
149	Safe Flight 21 Pre Investment Analysis Cost Benefit Analysis Phase II Report,	, FAA	05/09/01
150	Simulation of ADS-B using VDL Mode 4 in the LA Basin and Core European Airspace, , Version 3.0,	Swedish CAA	June 1999.
151	Summary of the Functional and Technical Assessment of the ADS-B Link Architecture Alternatives, Interim Report,	FAA	November 2001
152	Technical Link Assessment Report, ADS-B Technical Link Assessment Team (TLAT),	FAA Eurocontrol	March 2001
153	UAT Performance in the presence of DME/TACAN and JTIDS/MIDS, John Hopkins APL, AMCP/WGW/WP16,	AMCP	May 2002
154	VDL Mode 4 in A-SMGCS – Performance Simulations,	LFV	January 2002
155	World Airline Report	ATW	2000
156	Performance Review Report 2	PRU	1999
157	Annex to PRR4	PRU	2001

Ref no.	Title	Publisher	Date
158	Performance Review Report 5	PRU	2002
159	Aviation Safety Review	CAA	1990-1999
160	ECAC Ground and Taxi Accidents Rates	ECC	2001
161	Airline Economics Task Force Report	IATA	1997
162	Airline Insurance: An introductory Guide http://public01.rita.it/generali/library/airline/insmarket.html http://public01.rita.it/generali/library/airline/insmarket.html	Generali Group	1997
163	ALLPIRG/4-WP28 Appendix – Cost tables for CNS/ATM planning and evaluation tools http://www.icao.int/icao/en/ro/allpirg/allpirg4/wp28app.pdf	ICAO (CNS/ATM Sysmtems Implementation Advisory Group)	Summer 2000
164	Aircraft Accidents/Incidents and ATM Contribution: Review and Analsis of Historical Data (SRC DOC 2)	Safety Regulation Commission, Eurocontrol	October 2001
165	The Case for Enhanced Surveillance in Europe Annex 2.1 – Fast Simulation of Karlsruhe UAC	Eurocontrol	