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ATN IMPLEMENTATION TASK FORCE

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Executive Summary

This report, produced by the EATMP ATN Implementation Task Force, presents a strategic business analysis for the implementation of the Aeronautical Telecommunication Network (ATN) as the integrated data communications network serving aviation in Europe.

OVERVIEW AND APPROACH

This strategic analysis considers the aeronautical data communications needs of the ICAO EUR Region as they will evolve in the period up to 2015. In particular, it takes account of the communications enablers needed in support of the operational improvements defined in the ATM Strategy for 2000+. It also gives consideration to the operational needs of airlines and airport operators as well as ATS providers.

The approach adopted by the Task Force to develop the analysis has concentrated on two main aspects. Firstly, demonstrating that there is a need for a suitable strategic long-term solution for a common aeronautical data communications network, and, secondly, demonstrating that the ATN will be the most appropriate and cost-effective solution.

KEY FINDINGS

The Need for Enhanced Aeronautical Data Communications

Overall, data communications growth in the aeronautical sector is expected to be exponential, with composite growth in air-ground communications of between 2 and 3 orders of magnitude during the period 2000 - 2015. A broadly similar level of growth is also likely in ground-ground data communications. This means that the communications infrastructure as a whole will have to be expanded to have well in excess of 100 times its existing capacity.

The development of future ATM services in Europe is set out in the ATM Strategy for 2000+. This document clearly indicates a dependency relationship between the desired operational improvements that will deliver operational benefits, and the communications infrastructure as a key enabler of those improvements. It is important to recognise that the strategic direction set out in ATM Strategy for 2000+ is highly dependent on the development of more effective communications between stakeholders and a number of its provisions affect ATSOs, AOs and APOs alike.

Nearly all of the operational improvements foreseen in the Strategy are dependent on ground data communications and just over half require the introduction of air-ground datalink for ATS messages, initially for non-time critical messages and later for time-critical and/or safety critical communications.

However, the communications infrastructure is not just an issue for ATM. The airlines are increasingly reliant upon data networks (air-ground and ground-ground) for their own operations. The amount of datalink traffic for AOC messages is rising rapidly as more aircraft are equipped with datalink and individual aircraft transmit and receive more data. The saturation of the ACARS service, and its general obsolescence, place a strong requirement for a modern replacement. For the airports, there is also a growing dependence on data communications to support integrated airport information systems, wide area communications links and datalinks with aircraft and ground vehicles.

The communications service enhancements that are going to be needed within the aviation industry, place certain demands on the communications infrastructure. Firstly, there must be full connectivity, addressability and inter-operability between all systems/stakeholders that need to communicate, including transiting aircraft; secondly the information content must be intelligible to all users, requiring standardised data formats and protocols; and thirdly wide-area information sharing introduces new risks to data

integrity and stringent requirements for data security combined with ease of access for legitimate users. All of these lead to the need for a common, integrated communications network able to handle all the relevant services in a seamless and transparent manner, regardless of location.

Because the aircraft is the common denominator in all the air-ground datalink applications, there are strong arguments for a common infrastructure to handle AOC and ATS message traffic.

The existing communications infrastructure serving the aeronautical industry is fragmented with a variety of networks of different ages using different technologies, some of them application specific. This situation has two main drawbacks: it is not cost efficient and not ideal, in architectural terms, for providing large scale increases in communications capacity and new applications.

A viable networking solution for aeronautical data communications must meet the operational requirements that stem from the operational improvement initiatives of the stakeholders, only then will operational benefits be delivered. As a key enabling infrastructure, the communications systems must also meet the technical and non-operational requirements that will ensure that a cost-effective solution is implemented.

These requirements, combined with the exponential data communications growth not only present a challenge to the network designers, implementers and managers, but also mean that most, if not all, of the existing infrastructure will be rendered obsolete. In short, it is reasonable to expect that the existing network elements will be replaced anyway, so that the argument is not so much about whether to have new networks but is more about defining a scalable architecture within which these new networks can be integrated.

The Case for a Common Aeronautical Data Communications Network

Aeronautical Data Communications is a global market with many stakeholders, a rapidly growing number of new communicating entities (aircraft, operators etc) and a high growth rate in the volume of communications. Against this background, the operational, technical and non-operational communications requirements of the future can only be met in full by a solution that qualifies as 'strategic' against defined criteria.

The strategic solution must be able to develop and satisfy the capability and performance needs of all stakeholders throughout the period in question. Its ability to consolidate all the data communications needs of the users is critical (e.g. ATS and AOC datalink messages for an aircraft operator; air-ground and ground-ground ATS messages for an ATS provider and so on). Furthermore, the solution chosen must be able to support an incremental migration from existing networks with minimum unnecessary cost and disruption, taking advantage of any windows of opportunity that arise.

The findings of the analysis indicate that, in the event that a non-strategic solution is chosen, there would be potentially serious shortfalls in capability and performance, in respect of some requirements. Whilst the shortfalls could in theory be covered by work-arounds, that would incur additional costs. By the time the deficiencies have been corrected it will come to resemble a strategic solution in some criteria whilst remaining ad hoc and inefficient in other ways.

If the shortfalls against operational, technical or non-operational requirements are significant, as they could well be, then a non-strategic solution is unlikely to be economically justifiable. In any case, accepting an increasing shortfall in communications capability and performance will not be acceptable when it starts to seriously constrain air transport operations and when there is no fundamental technological reason for the shortfall.

On the basis of this analysis, there is a strong case for moving to a strategic solution, at the first window of opportunity.

The next issue is to examine the alternative solutions that might provide a solution. The ATN is the only comprehensive solution that has been proposed so far that is designed from the outset as a strategic solution for the whole aeronautical data communications infrastructure. The main alternative is to continue the development of the existing communications infrastructure in a more ad hoc fashion. A Baseline Scenario has been therefore set out, that defines the expected evolution of the aeronautical communication infrastructure in the EUR Region under a 'laissez faire' scenario, in the event that ATN is not implemented.

Feasibility of the Baseline Scenario

In the baseline scenario, the existing networks would be incrementally enhanced to try to meet the changing communications requirements. However, a number of different networks would remain, operating to different standards and protocols with different applications.

The feasibility assessment of the baseline scenario indicates that it will fail to meet the requirements by varying degrees in a number of areas. A number of significant shortcomings have been identified and it is concluded that these are too numerous and significant for it to be regarded a feasible option for satisfying the requirements of the future European aeronautical data communications infrastructure. .

Feasibility of the ATN Scenario

The ATN scenario calls for three Phases of implementation. The sequence starts with ATN air-ground datalink services over VDL Mode 2, then builds up the ground infrastructure and adds further air-ground subnetworks, common functions and support for additional end system applications, until the full ATN has been implemented for air-ground and ground-ground services throughout the EUR Region.

The findings of the feasibility assessment show that the ATN based infrastructure should be capable of satisfying, in full, all the operational and non-operational requirements. The ATN may, therefore, be considered as both technically and operationally feasible as a strategic solution for the whole of the aeronautical data communications infrastructure. It should be able to provide air-ground datalink services and ground-ground communications in a fully integrated, seamless and effective manner.

ATN Costs and Benefits

The analysis has identified the major cost and benefit drivers for different phases of the implementation of ATN. It has not been possible at this time to construct a standard cost-benefit financial case due to the lack of quantified data for ATN product costs and operational benefits. The financial appraisal has, therefore, to remain largely qualitative for now. Nevertheless, the study has led to the following results.

The benefit drivers clearly demonstrate the potential of incremental efficiency and effectiveness gains for all stakeholders over the three phases of ATN implementation. In particular, reduction of ATC delays and ATC charges are drivers of the Operational Improvements set out in ATM Strategy for 2000+. Data communications, and in particular air-ground datalink, are enablers for a majority of these improvements.

The costs and benefits of aircraft equipage in Phase 1 are dominated by AOC and CPDLC services, reflecting the replacement of the ACARS service and extension of air ground datalinks to include ATS applications.

The maximum benefit gain is expected to emerge through Phases 2 and 3 as the networks are extended to all stakeholder groups, with a wider set of supported end system applications.

Convergent technologies and the need to minimise costs provide a powerful incentive for a common infrastructure to enable air-ground datalink services for AOC and ATS communications.

The result of a C/AFT analysis, for the USA, supports the view that the introduction of VDL Mode 2 based datalink services provides sufficient ATC and AOC benefits to provide a strategic long term investment with reasonable return. The C/AFT analysis concludes that forward fit equipage for AOC applications is low risk with a good return on investment whilst retrofit equipage is driven by ATC applications that should provide delay reduction benefits to offset high installation costs. The AOC situation, however, may not be the same in Europe and will need to be investigated further. C/AFT has used a statistical approach, to deal with the uncertainty and availability issues of quantified financial data, which can be adapted to be used with European data.

The FAA's analysis indicates that cockpit HMI issues present an obstacle to the retrofit of CPDLC functions in aircraft. This needs to be explored further in the context of determining viable transition paths and their associated costs.

The main issue for the financial analysis is the lack of available cost/benefit data, therefore further quantification is required to fully justify investment in ATN. The assumptions that will be used to build the European Business Case will need to be clearly stated and refined over time. Simulation programmes and operational trials, such as PETAL IIe, will provide useful data that is needed to calibrate and verify the quantitative assumptions and parameters used.

A new framework has been defined, incorporating the C/AFT approach, to solve the financial data issues for the ATN Business Case. In carrying this forward, the underlying assumptions and input parameters used by C/AFT will need to be modified to be consistent with the European ATN scenarios as defined in the Proposed ATN Implementation Plan.

Stakeholder Incentives

A Strategic incentive reinforces a need and helps to provide a 'pull' in the desired direction and thereby encourages early adoption. It is consequently most effective at the beginning of the implementation when it can reduce the lead-time needed to start the implementation rollout. In the present case it has to provide compelling evidence to all stakeholder groups that it is their collective responsibility to enable the necessary future ATM system improvements by investing in datalink.

A financial incentive focussed on the aircraft operators is already being applied in US for the migration from ACARS to VDL-2 based AOC. There is currently no direct financial incentive for aircraft operators to equip for ATC purposes, therefore, the possibility of using a differential route charging policy and system to create appropriate financial incentives needs consideration.

In the longer term there may also be an incentive for airport operators to provide mobile datalink services as part of a total service package to attract customers.

In the case of ATS Providers the opportunities for financial incentive are less clear, given the way that 100% of their costs are recovered through the Route Charging System.

Implementation directives apply, in principle, to all stakeholders. They will have to be used to ensure fair competition and a clearly defined end date of the migration to datalink.

CONCLUSIONS AND RECOMMENDATIONS

Overall, the Task Force has concluded that achievement of the operational improvements, that have been identified in the ATM Strategy for 2000+, will be highly

dependent upon the timely availability of enhanced aeronautical communications. There is a well founded strategic case for a common, integrated communications infrastructure, and ATN represents a feasible solution that should satisfy the aeronautical data communications needs for the foreseeable future.

The lack of good quality, relevant, quantified financial data means that it is not possible, at this time, to provide a fully justifiable financial case for ATN. The use of the C/AFT methodology is sound and adds particular value through its ability to handle uncertainties in the underlying data.

The ATN Implementation Task Force makes the following specific recommendations:

1. The Task Force, having found that there is a strong strategic argument in favour of the ATN, recommends that the strategic case is endorsed.
2. In common with other organisations working in the same field, the Task Force recognises a severe lack of reliable, quantified cost and benefit source data. It therefore recommends that:
 - a) The importance of simulations and other actions already being undertaken to obtain improved cost-benefit data are confirmed and reinforced;
 - b) Initiatives are launched, as may be required, to obtain data of sufficient quality to construct a full cost-benefit assessment of the first phase of ATN-implementation in Europe that would justify stakeholder expenditure and, in particular, support a robust Business Case for Link 2000+;
 - c) The decision to adopt the C/AFT probabilistic analysis method to support the building of the European ATN Business Cases is endorsed.
3. Based on the need to achieve a critical mass of users as soon as possible, the Task Force recognises that a combination of incentives and mandatory equipage are likely to be required to encourage timely action and adoption of the ATN by stakeholders. It recommends that action is initiated to develop and assess incentive mechanisms that will ensure the success of the implementation, specifically that:
 - a) The European Notice of Proposed Rule Making procedure is initiated as soon as sufficient information on implementation planning is available, to ensure that the mandating of equipage is supported by a majority of stakeholders;
 - b) Proposals are developed for a differential Route Charge mechanism, for presentation at ACG.
4. Given the importance of 'Windows of Opportunity', the Task Force recommends that relevant windows of opportunity are identified and exploited in the Link 2000+ implementation programme, also that they are taken into account when formulating incentive mechanisms.

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1. INTRODUCTION

This report presents a strategic business analysis of the implementation of the Aeronautical Telecommunication Network (ATN) as the integrated data communications network serving aviation in Europe. For the convenience of the reader, a brief overview of the ATN is provided at Annex A. A set of references used in this report, shown in [] throughout the text, is included at the end of this document.

1.1 Background

EUROCONTROL, ICAO and industry studies have independently concluded that air traffic movements are forecast to continue to increase on average by 4.6% [9] per annum up to and beyond 2010 and that the active aircraft fleet is increasing by 3.1% per annum [123, section 4.6]. Consequently, demand will continue to grow significantly into the next century to a point where the current air traffic management (ATM) will be unable to cope, resulting in intolerable delays to aircraft operators and passengers alike. In addition, in the current market of deregulation and privatisation of the air transport industry there is also a growing pressure from aircraft operators on the ATM service providers to meet the users' flight efficiency and flexibility needs, and to minimise costs.

The European Air Traffic Control Harmonisation and Integration Programme (EATCHIP) was initiated in the early 1990's to reduce the increasing air traffic control (ATC) delays that had been experienced through much of the 1980's. The process of Harmonisation and Integration applies to communications networks as well as to the whole ATM system. Indeed, it is not possible to achieve one without the other. The programme has resulted in a number of current and planned initiatives that have the common objective of increasing capacity and thereby reducing ATC delays. This now continues in the context of the European Air Traffic Management Programme (EATMP) that is the successor to EATCHIP.

In order to improve the performance of the ATM Services with greater capacity, greater efficiency and increased safety, it will be necessary to introduce a range of operational improvements during the next two decades. Achieving the improvements will require new operational and technical concepts to be phased in, together with enabling improvements to the supporting infrastructure. Recent analyses [15, volume 2, Appendix 2] have shown that many of the operational improvements that are foreseen will require data communications enhancements and that, among these, air-ground datalink is a particularly important 'enabler' upon which many of the operational improvements will depend.

Another consequence of the growth in air traffic, coupled with the airlines' developments in the efficiency of their own operations, is a rapid expansion of the use of Airline Operational Communications¹ (AOC) applications. This is leading to congestion in the ACARS air-ground datalink services used for AOC, to the point where airlines' operational efficiency is likely to be adversely affected. Concern within the industry has led to significant interest on the part of airlines, and their principal communications service providers (notably ARINC and SITA), in the future evolution of network technologies and datalink services.

The ATN has been specified and designed as the strategic solution for the advanced communications infrastructure that will be needed in the future. It is designed to be capable of handling all types of aeronautical communications traffic, in particular AOC and ATS datalink communications services. The impending need to introduce datalink services for ATS applications, coupled with the urgency of the requirement for a second

¹ For the purposes of this analysis, AOC communications are assumed to include Airline Administrative Communications (AAC).

generation AOC datalink, means that there is an immediate window of opportunity to start the European implementation of ATN. Given the lead times involved, an early implementation start is crucial. Indeed, events have been moving rapidly during the time that this analysis has been in preparation, to the extent that visible momentum is building behind ATN acceptance and moves have been made towards the launch of implementation programmes on both sides of the Atlantic. For instance:

- ARINC has launched a VHF datalink service in Europe, with SAS as launch customer committed to fleet-wide implementation of VHF datalink [54, 55]. ARINC will initially deploy ACARS but with firm commitments to implement ATN-compliant VDL Mode 2 in the near term.
- In October 1998, the FAA Joint Resources Council (JRC) approved funding for the CPDLC Build 1 and Build 1A program. This program comprises the US domestic implementation of ATN over VDL Mode 2 enabling the deployment of (a limited set of) CPDLC services in Miami airspace first (Build 1) and at all US domestic en-route centres in a second step (Build 1A). The JRC decision is an important milestone for ATN implementation. Backed up by the commitment and proactive support of major US Airlines, this decision will force the pace for ATN roll-out in other regions of the world, too [119].
- The reported plans of FAA also include moving to its VDL Mode 3 based concept (NEXCOM) in the medium term [119].
- The CNS/ATM Focused Team (C/AFT) is a co-operative airline forum that also involves aircraft manufacturers, the EUROCONTROL Agency and the FAA. Its Data Link Focused Group has prepared and presented in late 1998 an airline-oriented cost-benefit analysis for the introduction of ATN-based VDL Mode 2 datalinks for AOC and CPDLC communications in the US. (See Chapter 5 of this report for discussion of the applicability of the C/AFT model to Europe).
- A co-operative programme is under development for the deployment of AOC and ATC datalink services based on ATN and VDL mode 2 in Europe. This programme is currently referred to as the Link 2000+ programme.
- The PETAL II trials have been extended to include trials of ATN air-ground communications with in-service aircraft, including those of American Airlines. PETAL IIe will aid the definition and convergence of compatible implementations on both sides of the Atlantic.
- Development of commercial ATN products (portable ATN software, ground routers, air server, avionics etc) is well underway. For instance, avionics manufacturers including Sextant, Honeywell, and Allied Signal, are members of the ACI consortium which is producing certifiable (DOC 178B level C) Avionics ATN Communications software for their customer ATNSI (a consortium of 14 US airlines). Each ACI member plans to offer certified avionics equipment based on this software to support both ATC and AOC services. In addition to this Rockwell-Collins will supply a CMU based on the same ATN products for use on the American Airlines aircraft in the context of the PETAL II extension project due for delivery in 2001. All manufacturers plan to offer VDL Mode 2 as the primary subnetwork in the short term, augmented by AMSS and future VDL Modes (3,4) later. Aerospatiale plans to provide its FANS-B product supporting ATN functionality in the 2002/3 timeframe.
- The CAERAF project is in progress. The objective of this project is to provide a comprehensive test facility for ATN systems and services to support system certification and operational approval prior to deployment of these systems in the operational environment. This project is a joint venture between EUROCONTROL, FAA and ATN Systems Inc.

- Major US Airlines are in the process of preparing ATN implementation plans
- The German ATS provider, Deutsche Flugsicherung (DFS), has developed a first iteration of an ATS Data Link Strategy [129], responding to airline needs and forecast shortcomings in the ATC system. The DFS has recognised the shortcomings of the current environment, i.e. resulting from increasing numbers of aircraft leading to frequency congestion, increased controller workload, potential mis-understandings of R/T voice communications, lack of automated exchange of data between air and ground systems and failure to meet airline requirements for datalink. The datalink services considered specific to the DFS include (1) D-FIS (2) CPDLC and (3) ADAP. DFS expects use of VDL Mode 2 as the initial and primary ATN compatible datalink. DFS has studied the implications of implementation of the required data link services on their operational ATM systems and processes and identified comprehensive needs for modifications in order to achieve datalink compatibility. A phased implementation scenario has been defined: Phase 0 - Initial Data Link Applications (ACARS based, 1999); Phase 1 - Non-time critical services (from 2005); Phase 2 - Time-critical services (2007, depending on the justification of an operational requirement for time critical services). The DFS conducted a cost/benefit study which, whilst supportive of datalink implementation, was not considered to be a sufficient sole basis upon which to implement. Due to a large number of unknowns and the difficulties associated in quantifying benefits and costs, a final cost benefit ratio could not be calculated. Nevertheless DFS recognises a strategic requirement to introduce Air-Ground Data Link services within DFS controlled airspace.
- Work has been launched to investigate the integration of STDMA/VDL Mode 4, TCP/IP and Asynchronous Transfer Mode protocols into ATN. In particular, the growing basis of TCP/IP implementations in the aeronautical communications environment results in the need to define the means for co-existence with ATN in the ground infrastructure.
- VDL Mode 3 is being studied, as a medium term sub-network, by several parties.
- As a transitional step in the migration to ATN, ACARS Over AVLC (AOA) has recently emerged as an optional arrangement for handling AOC applications over VDL Mode 2 datalink in the short term (to relieve ACARS congestion). Airlines retain the choice of going straight to ATN. AOA is not expected to be used to any significant extent for ATS applications [11].

1.2 Scope of the Strategic Business Analysis

The strategic business analysis considers the data communications needs of the ICAO EUR Region as they will evolve in the period up to 2015.

It takes account of the developments in ATM concepts and operational systems foreseen in the ATM Strategy for 2000+ [15]², a document that is being formulated by EUROCONTROL in collaboration with the main stakeholders in European Air Transport, for the subsequent ratification by Ministers scheduled for 28 January 2000.

For the purposes of the strategic business analysis, an ATN Implementation Plan [123] has been set out, that is compatible with the ATM Strategy for 2000+. It elaborates how the aeronautical data communications environment will evolve, across a range of operational contexts, in the period up to 2015. Particular attention is paid to the differing

² It should be noted that the geographic scope of ATM Strategy for 2000+ is ECAC Europe whereas the scope of the Analysis is ICAO EUR Region that includes a number of additional States, as set out in the ATN Implementation Plan [123] section 2.1.

situations in the high traffic density core area of Europe, the surrounding lower traffic density areas and the remote areas.

The data communications needs considered in the analysis encompass aeronautical mobile and fixed communications, where the communicating parties include: aircraft, airline operations centres, air traffic control centres, airports, ground-based mobiles and other entities such as meteorological services. This naturally includes ground-ground and air-ground communications services carrying message traffic for ATS and AOC purposes.

The aviation industry has a long history of growth in its operations and continuing evolution in its systems and infrastructure. The strategic business analysis consequently has to take account of the ongoing process of transition, from today's systems to those of the future, that will occur as investments are made and operational advances achieved.

The strategic business analysis considers how the Aeronautical Telecommunications Network (ATN) proposition will appear from the perspectives of the key stakeholders: the aircraft operators (AOs), airport operators (APOs) and air traffic service provider organisations (ATSOs). The involvement of the third party Aeronautical Communications Service Providers (ACSPs) is also given consideration where relevant.

1.3 Objectives and Requirements of the Strategic Business Analysis

The principle objectives for the ATN strategic business analysis are to:

1. Examine the trends and requirements driving the need for an enhanced aeronautical communications infrastructure.
2. Identify the linkages between the development of the enabling infrastructure that drives the investment costs and the operational improvements that will deliver benefits.
3. Establish the strategic case for a common aeronautical data communications network.
4. Investigate the suitability of the ATN for meeting that need and compare it with a 'laissez faire' baseline scenario that assumes the retention and development of existing networks.
5. Investigate the cost and benefit drivers of the ATN, at least qualitatively in the absence of reliable quantitative data; in order to contribute to the financial justification for implementing the ATN (i.e. Business Case)³.
6. Identify incentives for stakeholders (Air Traffic Service Providers, Aircraft Operators, Airports, Communication Service Providers, industry) to research, develop and implement the ATN.
7. Guide the ATN implementation planning process.

³ The original terms of reference for the ATNI Task Force called for the production of a 'cost/benefit report' as one of the Task Force's deliverables. It has not been possible at this time to construct a standard cost/benefit financial case due to the lack of quantified data for ATN product costs and operational benefits. Instead, the scope of the deliverable was amended to become the 'Strategic Business Analysis for ATN', presented here.

1.4 What Needs to be Demonstrated in the Strategic Business Analysis

The strategic business analysis has to provide arguments at two levels.

1.4.1. Level 1: The Argument for a Strategically Conceived, Integrated Network Architecture

At the first level, the analysis has to demonstrate, with a compelling rationale, that there is a strategic need for a common aeronautical data communications network, (in the form of a strategically conceived, integrated network architecture), to serve the operational needs of the air transportation industry as it evolves during the next two decades. The pivotal role of air-ground datalink within the strategic network needs to be exposed within this analysis.

The argument needs to be formulated mainly by considering the operational needs and developments in the aviation sector, where advanced data communications capabilities may be a vital enabler for important operational initiatives. It needs to be explicit about the different perspectives of the stakeholders in the aviation sector, particularly the airlines, airports and ATS providers. Each of these experiences different business pressures, barriers to development and competitive challenges, for example. Their interests are naturally divergent in some respects and this colours their attitudes to investment priorities.

For the strategic argument to be carried, all parties must be convinced that a strategically conceived, integrated network architecture is a necessary enabler for future progress. The subject is addressed in detail in chapter 3.

1.4.2. Level 2: The Argument for ATN as the Most Appropriate Solution

At the second level, the analysis has to demonstrate that the ATN is the most appropriate strategic solution overall, and in particular for the provision of datalink services, that could offer the best value for money in relation to the capabilities that must be provided.

This argument, namely that the ATN is the most appropriate solution, relies on consideration of feasibility and cost-effectiveness.

This approach consists, for the time being, of 2 distinct analyses:

1.4.2.1 Analysis of Comparative Feasibility

In order to compare the relative merits of non-strategic and strategic networking solutions, two scenarios have been developed. The first of these, detailed in Annex C, postulates a 'baseline scenario' for how the aeronautical data communications infrastructure is likely to evolve on a non-strategic, 'laissez faire' basis, if the ATN is not adopted. The second is the ATN Scenario, detailed in the Proposed European ATN Implementation Plan [123] for evaluation as a candidate strategic solution.

The Baseline and the ATN scenarios are then individually compared to the operational and non-operational requirements, to investigate likely feasibility and identify where the main differences might lie. The aim is to confirm, in each case, the suitability or otherwise of the scenario, in terms of its ability to meet the requirements, and to record and analyse any areas where a scenario is likely to suffer a shortfall in capability or performance.

The results of this analysis are presented in Chapter 4 and detailed in Annex C.

1.4.2.2 Analysis of Cost and Benefit Drivers

The second analysis consists of investigating the cost and benefit drivers at each phase of the ATN implementation, at this time in a qualitative way, and considering the issues involved in producing credible quantitative arguments in the future.

As part of the analysis, consideration is given to recent studies carried out in North America to see whether the results obtained and the methods used are relevant to Europe.

This analysis is presented in Chapter 5.

1.4.2.3 Limitations of the Analysis of Costs and Benefits

Perhaps the greatest challenge for the analysis described in this report has been to obtain reliable data about the future operations, equipment and systems that will be implemented in the period up to 2015, yet which are still in various stages of being defined.

The further into the future one looks, the sparser the information that is available. At the time of writing, first generation ATN products are still in development and manufacturers are not generally in a position to provide pricing information. There is also very little quantified evidence in existence concerning the future operational benefits for which ATN would be an enabler. The lack of reliable quantified information is perhaps to be expected when considering longer-term strategic investments of this type.

As a consequence, the analysis presented here does not attempt to construct a classical cost-benefit model or financial business case for ATN. It does, however, point to a number of considerations for the collection of quantified data and the future construction of a quantified business case for the European implementation of ATN.

1.5 Structure of the Report

This report describes the scope, approach, results and conclusions of the strategic business analysis for ATN. Supporting material is provided in the annexes.

In detail the report has the following chapters:

Chapter 2 sets out the requirements for the communications infrastructure and services.

Chapter 3 sets out the case for having an integrated, strategic communications infrastructure based on a common aeronautical data communications network.

Chapter 4 considers the alternatives ways of meeting the requirement and assesses the feasibility of the ATN and Baseline scenarios.

Chapter 5 analyses the cost and benefit drivers that would apply during each of the 3 phases of implementation of ATN. It also presents and interprets the quantitative cost and benefit results from the C/AFT and FAA analyses and discusses the European-specific drivers and context that would influence a European Business Case.

Chapter 6 discusses the kinds of incentives that could encourage stakeholders to commit to a strategic solution and more specifically adopt the ATN as their preferred solution.

Chapter 7 presents the overall conclusions from the strategic business analysis for ATN and the recommendations of the Task Force arising from it.

Annex A presents a brief overview of the ATN

Annex B presents more detail on the operational requirements for communications that are discussed in Chapter 2.

Annex C presents a feasibility assessment of the ATN and a 'baseline' scenario against the requirements set out in Chapter 2 and summarised in Chapter 4.

2. THE NEED FOR ENHANCED AERONAUTICAL DATA COMMUNICATIONS

In order to marshal the arguments for a strategically planned, integrated communications infrastructure in Chapter 3, it is first necessary to consider the factors driving change, aeronautical communications trends and the stakeholders' requirements, as set out here.

The sequence of material presented in this chapter is as follows:

- The status of the existing communications infrastructure is summarised, as the starting point for change;
- The business-driven operational needs of the key stakeholders are then discussed, followed by;
- A summary of the observable trends and associated factors influencing the evolution of the communications infrastructure;
- An analysis of the linkages between the operational improvements set out in the ATM Strategy for 2000+ and their communications enablers provides a clear indication of the items that will drive the detailed operational requirements in the future. This is followed by;
- A summary of the technical and non-operational requirements relating to the implementation and operation of the communications infrastructure.

A concluding section summarises the main findings of the analysis presented in this chapter.

2.1 The Existing Aeronautical Communications Infrastructure

Before considering the future requirements and evolution of the communications infrastructure, it is relevant to briefly summarise the status of current communications facilities, in order to assess the starting point from which improvements have to be made. A more detailed description of current networks is to be found in section 3 of the Proposed ATN Implementation Plan [123].

Communications in the aviation industry today use a variety of technologies and standards for airborne and ground equipment and protocols. Implementations have largely been designed and carried through at a local level within States and by individual organisations. The result is a set of networks of varying age, quality and performance, some of which are application-specific, some national and some international. There is significant fragmentation and variation in terms of:

- Technologies used for specific types of communications.
- Network and proprietary standards and protocols.
- Network architecture, design and planning.
- Local implementation timescales.

For international networks, there is a continuing trend towards convergence of standards for reasons of compatibility. National and local network arrangements are more variable across Europe. In many cases, the practice for adding new communications capabilities (e.g. to support the introduction of new applications) has been to graft on yet another dedicated-purpose network.

The result is that there is not one aeronautical communications network but many operating in parallel, some dedicated to specific types of message traffic and many with significant local and regional variations. In addition, a number of networks (air-ground and ground-ground) are based on outdated technologies that have limited capabilities and poor cost-effectiveness. The implications of this are, inter alia:

- (a) Aircraft operators incur extra costs because aircraft have to carry a multiplicity of communications-related avionics devices, antennas etc, in order to satisfy airline and ATS communications needs and to utilise the different services that may be available in different locations.
- (b) Information sharing is hampered because end-to-end connectivity across multiple wide area links may be obstructed by the use of different protocols and message formats, even where gateways interconnect the dissimilar networks.
- (c) There is no common aeronautical data communications network, in the sense that ATS communications are currently treated as a separate domain from airline and airport communications and have their own dedicated infrastructure, one reason why aircraft have to carry a variety of communications systems.
- (d) Seen at a European or global level there is avoidable replication of costs associated with the design, implementation and management of the networks.

The Baseline Scenario mentioned in Section 1.4.2.1 above, and further discussed in Chapter 4 and Annex C, is based around the continuing evolution of these existing communications facilities.

2.2 Operational Needs of the Key Stakeholders

Each group of stakeholders has business pressures that lead directly or indirectly to an operational need for enhanced communications capabilities in the future. These are summarised in sections 2.2.1 through 2.2.3 for ATS Providers, Airlines and Airports respectively.

2.2.1 ATM Capacity Issues

The European ATM system is approaching a point of saturation at which delays are reaching record levels and there is a risk that currently planned operational improvements will not be sufficient to deliver the required performance.

In order to accommodate the expected traffic growth in the next 10 years, strategic measures are needed. These have been set out in the ATM Strategy for 2000+ [15]. The specific provisions of this Strategy and their implications for the development of the communications infrastructure are discussed in section 2.4.

Communications is an important indirect enabler of ATM operational benefits, through the operational functions for which it provides services.

2.2.2 Development of Airline Operations

Airlines operate in an increasingly competitive, deregulated market. They are continually seeking to reduce costs, maximise yields and enhance their competitive position via an ongoing process of improvements to their own operations and infrastructure.

Airline investments that are proposed or mandated by other aviation community stakeholders (e.g. the regulatory authorities, ATC community or airports) will always be strongly challenged to demonstrate that they provide necessary actual benefit and that the impact on airline expenditure is minimised. Airlines are looking for improvements that include: reduced delays, lower ATC charges, more fuel-efficient trajectories etc.

In the search for these improvements, airlines are expecting gains from more collaborative involvement in decision-making with the Air Traffic Services providers. This requires better information sharing and Collaborative Decision Making (CDM) is an important element of the ATM Strategy for 2000+ [15].

Increasingly, airlines are becoming dependent on AOC applications for efficient flight operations. The availability, reliability and capacity of AOC datalink services are considered of high importance. Saturation and frequency congestion of the existing ACARS datalink service is giving rise to considerable concern among airlines that are dependent on AOC. As a consequence there is strong airline interest in a next-generation AOC datalink to replace the existing ACARS service.

For the purposes of this analysis, airline operational improvements can be regarded as two distinct sets, namely those that:

1. Develop the airline side of co-operative/collaborative ATM and associated information sharing;

These improvements can be found in the Table 2 below

2. Enhance internal airline operations and airline administrative functions.

These are manifested by a growth in the number of AOC applications and user airlines as discussed in 2.3.1 below and in section 2.2.4 of the ATN Implementation Plan [123].

Communications is an enabler of airline operational benefits in the same way that is described for ATM.

2.2.3 Development of Airport Operations

Airports, in the same way as airlines, operate in an increasingly competitive, deregulated market. They are continually seeking to maximise their profits and their competitive position via an ongoing process of improvements to their own operations and infrastructure.

Inter-airport competition is becoming intense, particularly in the congested core area of Europe. One consequent trend that can be observed is the increasing differentiation and specialisation that is taking place among some airports, as they target particular kinds of users.

Many airports and airport groups that were formerly under state or municipal ownership are being commercialised and/or privatised with a consequent focus on their commercial performance. For many international airports, the commercial pressures are exacerbated by the imminent loss of duty free revenues within the EU.

Most of the busiest airports in Europe are capacity constrained by their physical infrastructure, including runways, taxiways, gates and terminal buildings. In many cases, the capacity constraints are made worse by environmental regulations restricting air movements and/or operating hours. Airport congestion is a primary cause of air traffic delays. One consequence of a lack of airport capacity is a constraint on the potential earnings of the airports concerned. This leads to a dual focus on a) extracting the maximum profit from the available air movements and b) finding ways to increase numbers of air movements to the maximum possible by increasing the utilisation of the physical infrastructure.

In the search for these improvements, gains are to be expected from improved co-ordination and information sharing between ATS providers, airport operators and airlines, something that is clearly recognised within the provisions of the ATM Strategy for 2000+ [15]. The need for airports to be able to handle the uncertainties and disruptions caused by flight delays, and their knock-on effects on airport operations, means that accurate, timely information is critical and is in turn dependent on an effective communications infrastructure.

A number of datalink applications are either already in operation at some airports or are currently in development. These are likely to become important in addressing problems such as low visibility capacity and surface movement congestion.

Improved information flows within airport operations are manifested by growth in the number of integrated information systems implemented at airports.

Growth in the number of wide area communications emanating from the airport is also likely as a result of this integration [123, section 2.2.5].

Airport operational improvements can be regarded, for present purposes, as two sets that:

1. Develop the airport side of co-operative/collaborative ATM and associated information sharing. (*These improvements can be found in Table 2 below*).
2. Enhance airport operations.

Communications is an enabler of airport operational benefits in the same way that is described for ATM.

2.3 Trends in the Evolution of the Communications Requirement

The need to develop the capabilities and performance of the aeronautical communications networks is influenced by a number of identifiable trends and factors:

2.3.1 Factors Affecting Required Communications Capacity

The expected growth in aeronautical data communications is driven by several factors.

2.3.1.1 Air Traffic Growth is Increasing the Volume of Communications

During the period 2000-2015 air movements in Europe are expected to grow to at least double present levels [15]. This means that the aircraft fleet will probably also double in numbers, assuming that there is no major change in average aircraft size or load factor over the long term.

2.3.1.2 The Number of Datalink-Equipped, Communicating Aircraft is Increasing

At the same time that the number of air movements is growing, the proportion of aircraft equipped for data communications is also growing, as fleets are progressively equipped for AOC and, as CPDLC and other ATS-related services come into operation, ATS communications over datalink.

The number of aircraft equipped for data communications is growing rapidly. Until now major European airlines have carried out experiments with datalink for AOC purposes and a few have installed it fleet-wide. Lufthansa was one of the European pioneers, taking the decision for fleet-wide installation in 1989 with 96% of its aircraft equipped by 1998 [29]. In Europe there are a number of ACARS roll-outs in progress or being planned, some coinciding with the start up of ARINC services in Europe. SAS is one example: from initial experiments in 1992/3, the decision was taken to install ACARS first on the long haul fleet from 1995 then on the short haul fleet from 1996, for a fleet-wide installation by 2000/1 [55].

2.3.1.3 Development of the ATM System is Increasing Automation of Information Flows

The overriding theme in development of the ATM system is one of integration and automation of processes, with the main aim of increasing capacity. As the systems for the real-time tactical functions of ATM are enhanced, we are seeing a progressive increase in automation of the information processing tasks and decision support

processes for ATC [15]. An important component is the progressive integration of airborne and ground-based functions using air-ground datalinks.

For this automation to be successfully implemented, the information used by the processes has to be available to the computer systems, requiring local and wide area data communications. As a consequence, there will be a large increase in data communications, first of the non-critical ATC messages then increasingly of those that are mission critical. This is ultimately likely to include both time critical and non-time critical safety messages.

To support these changes, aeronautical communications are expected to move to digital networks where today analogue communications are used, especially for the air-ground links. Analogue voice communications will slowly move into a role where they are used mainly for non-routine and emergency communication. Part of the reason for this change is that more and more of the information content in the communications will be generated by, or need to be read by, computer systems.

These developments place ever-stronger emphasis on the data communications infrastructure needed to service the new applications. This applies to both air-ground and ground-ground data communications as demonstrated in Tables 2a through 2d.

2.3.1.4 As New Applications are Implemented, the Amount of AOC Data Communicated by each Aircraft is Increasing.

Newer aircraft communicate much larger AOC volumes

of data than older types (the B777 for instance generates 10 times more data than a B757 [56]) and average message numbers per flight and message sizes per transmission are growing dramatically. Lufthansa reports [29] that when it started using datalink in 1986 there were 6-8 messages per flight each of 60-100 bytes in length. Today the number of messages per flight has grown by a factor of 6 and the message length by a factor of 4. Both factors are set to grow further with future applications. SITA reports [56] that sophisticated users of ACARS are now sending 40 messages per flight and it has seen the message traffic grow from 7.7 million data blocks in 1991 to 60 million by 1996. ARINC data shows a multi-year trend with cumulative growth of 13% per annum in ACARS AOC data volumes [54] in addition to which ATS messages are expected to add further significant growth.

2.3.1.5 Estimates of Data Communications Growth

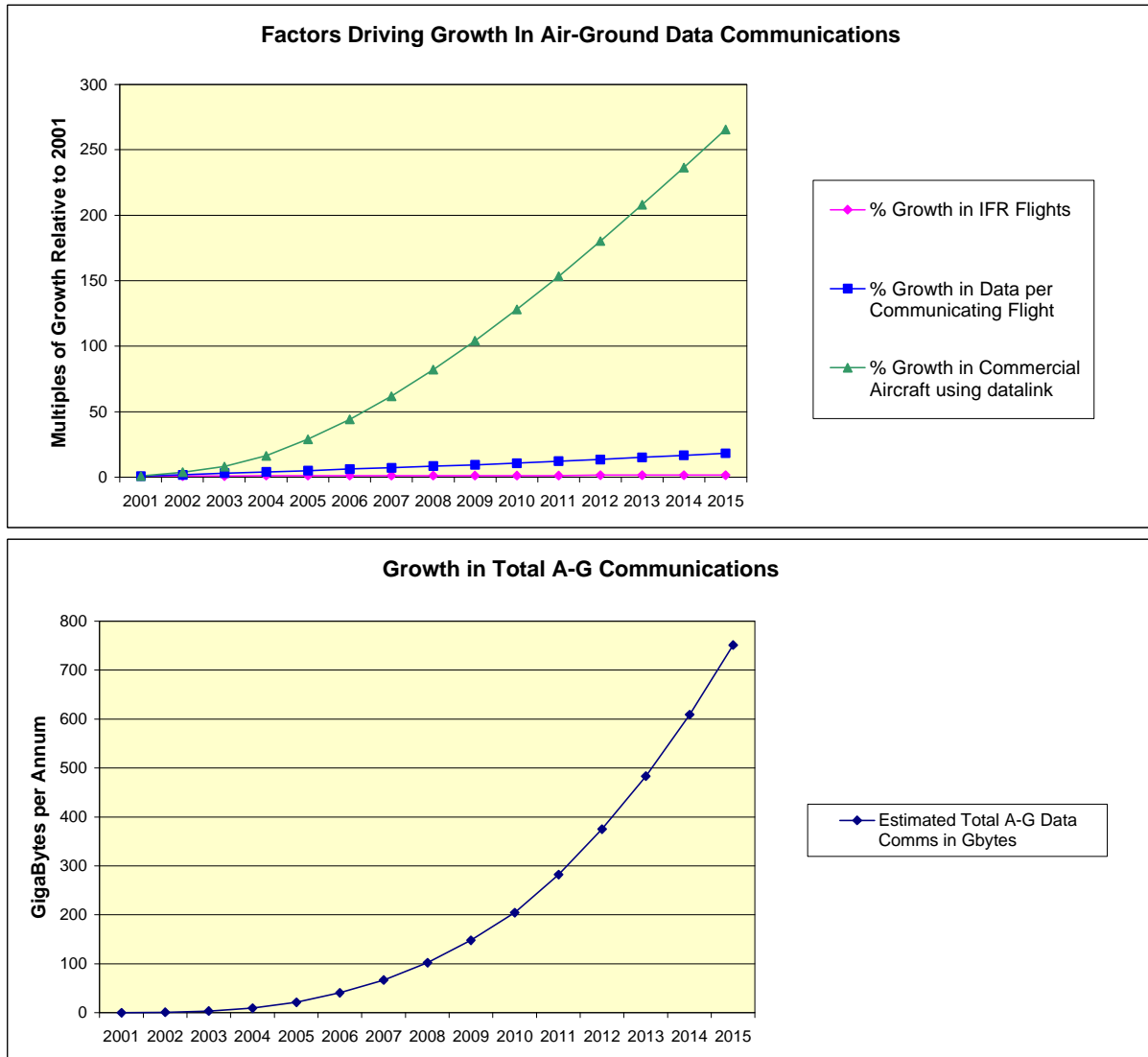
Taking into account the various factors and trends discussed above, estimates can be made of the potential growth in data communications volumes that will result.

In addition to the growth in air traffic, the proportion of the fleet equipped for ATS and AOC data communications is growing rapidly; and the data communications traffic, both air-ground and ground-ground, associated with each flight is also growing rapidly. In fact, the compounded growth rate for message traffic is likely to be much more rapid than that for growth in air movements. Growth will occur both in the number of communicating entities and the amount of information transferred. This has its roots in a number of underlying trends: the shift from analogue to digital modes of communications already mentioned; the trend to much more extensive sharing of information between the main actors in aviation – the airlines, airports and air traffic service providers; the move to a Gate-to-Gate ATM philosophy, the introduction of extensive collaborative decision-making in strategic, pre-tactical and tactical timeframes; and the introduction of sophisticated new end system applications on the ground and in the air. In parallel with this, the airline industry is already gaining experience of the benefits that derive from the use of data communications for AOC purposes. It is to be expected that there will be significant growth in the number of operators adopting these technologies and in the number and sophistication of the applications they serve.

Expectations of air-ground data communications growth are illustrated in the graphs of

Figure 1. The upper graph presents a view of the underlying factors driving growth in air-ground data communications based on the (probably conservative) data in the ATN Implementation Plan [123]. These multiply together to give the resultant anticipated total growth in Air-Ground data communications (lower graph)⁴. Other recent information from various sources tends to support these exponential growth rates.

Figure 1: Growth in Air-Ground Data Communications for ATC



On the basis of the analysis, it seems reasonable to expect that air-ground data communications volumes will grow by at least two and possibly in excess of three orders of magnitude over the 16 year period as indicated in Figure 1 (lower graph).

A broadly similar level of growth is also likely in ground-ground data communications, on the basis that, inter alia: there will be a range of new end system applications (such as CDM applications) driving growth in ground data communications; data traffic from the

⁴ These estimates do not include any allowance for ADS-contract applications, since it is not yet certain how and when ADS-contract might come into play as either a main (radar-substitute) or supplementary mode of surveillance in the higher traffic density (HTLA) areas of continental airspace in the future.

ATS and AOC air-ground applications will have to pass through the ground networks, and much of the ground-ground data is related to air movements and will grow as air traffic grows.

2.3.2 Factors Affecting Communications Economics

Commercial imperatives put constant pressure behind cost reduction and cost avoidance initiatives. This applies to communications services and infrastructure costs as to all other aspects of investment and operations.

Cost-effectiveness concerns consequently cover all aspects of network acquisition, operation and maintenance. Communications equipment has a useful economic life until the point at which it costs more to run it than to replace it with more modern technology. In an environment where a high rate of growth of capacity is required, the choice between expanding what exists and replacing it with something newer and higher capacity is an important economic decision.

2.3.3 Factors Affecting Required Integrity and Reliability of Communications

ATS applications have not really started to migrate to air-ground datalink, at least in core Europe. They will add significantly to the data volumes in future. Time-critical and/or safety-critical ATS applications will, in future, also place much more stringent demands on network integrity, reliability and predictability of performance.

This migration is discussed in the ATN Implementation Plan section 2.2.3 [123]. The implications for the communications infrastructure are significant in terms of the required integrity, resilience and security of the networks, the HMI design and the message traffic carried. In particular, they are important for the end-to-end performance of the communications services that need not only to guarantee appropriate service levels, but also to be able to detect and take corrective action in the event of communications degradation.

2.3.4 Factors Affecting Need for Improved Spectrum Utilisation

There is ever-increasing pressure on the finite resource represented by the radio frequency spectrum, as many different stakeholder groups compete for frequency allocations. Aviation is but one user community and the VHF frequency bands in particular, that are the basis of most aeronautical communications, are under considerable pressure. Severe frequency congestion has been seen in ATC communications in Europe and has led to the move to 8.33KHz channel spacing, amongst other initiatives.

The increasing use of ACARS VHF communications for AOC has also led to frequency congestion, first seen in North America but now becoming an issue in Europe, and is one of the most potent reasons for airline interest in ATN and VDL Mode 2 for AOC.

It is not just the VHF band that is congested, and all the aeronautical frequency allocations, including satellite frequencies, are potentially subject to problems as communications traffic grows.

As a consequence, any measures or technologies that can improve the management of frequency allocations and the utilisation of available bandwidth can potentially release additional channels and deliver benefit.

2.3.5 Factors Affecting the Need for Connectivity and Inter-operability

As aircraft operators expand the routes on which they offer their services, they wish to be presented with standardised ground systems with which to communicate, so as to avoid having to carry equipment specific to each geographic region. This becomes even more important when considering the fact that many aircraft are leased and will see service with different airlines and in different geographic regions.

Network developments therefore have to deliver new capabilities and levels of performance in order to meet requirements, in terms of: connectivity, capacity, integrity, bandwidth etc.

In addition to the new capabilities, productivity has to be improved so that the unit cost of communicating does not increase and preferably decreases in real terms. This leads to a need for globally standardised and compatible solutions to facilitate ease of acquisition and use. ICAO has an important role in setting the global standards.

The need for a strategic, integrated communications infrastructure is considered in Chapter 3 and the respective abilities of the ATN and the Baseline infrastructures to deliver the required operational and non-operational capabilities is the subject of Chapter 4.

2.3.6 Factors Concerned with System-wide Information Management and Information Sharing

A significant part of the capacity improvement of the air transportation system in future is expected to result from operational improvements to planning, in three ways:

- improved co-ordination between stakeholders in the planning processes, in particular through Collaborative Decision Making (CDM), operating within strategic, pre-tactical and tactical time horizons;
- better predictive information and data quality for improved planning accuracy;
- extended scope of planning with longer look-ahead periods and increased wide-area planning.

As recognised in ATM Strategy for 2000+ [15], the achievement of the operational benefits derived from improved planning processes (e.g. integrated slot planning, enhanced ATFM, multi-sector planning, etc) require information to be managed and shared system-wide. This will enable the stakeholder with the best (most accurate, most timely) information to share it with others requiring the same type of information. To achieve this places certain demands on the communications infrastructure in that:

- the system and the stakeholders must know where the information is held;
- there must be full connectivity, addressability and inter-operability between all systems/stakeholders that need to communicate, including transiting aircraft;
- the information content must be intelligible to all users, requiring standardised data formats and protocols;
- wide-area information sharing introduces new risks to data integrity and stringent requirements for data security combined with ease of access for legitimate users.

All of these factors lead to the need for a common, integrated communications network able to handle all the relevant services in a seamless, secure and transparent manner, regardless of location.

It is also for these reasons that CNS systems are described as the backbone of future ATM in ATM 2000+ [15]. Furthermore, among the component parts of CNS, Communications is an important enabling element of all surveillance systems and of such modern navigation systems as GNSS. This renders Communications as the key enabling infrastructure.

2.4 Communications as an Enabler of Operational Improvements in ATM

The ATM Strategy for 2000+ [15] mentioned in 2.2.1 describes a phased implementation of advanced ATM systems based upon the EATMS Concept of Operations [14], during the period through 2015. It has been especially driven in its selection of operational improvement initiatives by considerations of improving capacity, safety, flight efficiency and achieving minimum sustainable ATC costs.

Each operational improvement requires one or more enabling changes to the supporting ATM system infrastructure. Some items of enabling infrastructure also support more than one operational improvement. The tables 2a through 2c, below, have been derived from Volume 2, Appendix 2 of the ATM Strategy for 2000+ [15] and display a subset of the enablers described therein, selected for those that have a direct relationship with communications. The right hand column in each table indicates the stakeholders that are likely to be directly implicated in their implementation and use. Table 2d summarises the general themes that are also discussed in the strategy document that have implications for communications enhancements.

Table 2a: Illustration of ATM 2000+ Initiatives 2000-2004

Operational Improvements	AO/Airborne Comms Enablers	ATM/APO Ground Comms Enablers	A-G Data-link	G-G Data Comms	Stake-holders
Sector Optimisation and FUA		Advanced airspace management co-ordination tools (shared real-time information), Dynamic environment data management, Ground data communications infrastructure		Yes	ATSO, AO
Free Routes in Upper Airspace		Enhanced FDP systems and ATC tools, MET information		Yes	ATSO, AO
Continuous Route Structure Optimisation		Enhanced FDP systems, NAV infrastructure suitable for RNAV operations		Yes	ATSO, AO
Reduced Vertical Separation		MASPs indication in flight label			ATSO, AO
Improved Re-routing Functions		ADEXP message exchange; ground data and voice communications infrastructure		Yes	ATSO, AO
Enhanced Tactical ATFM		TACT developments, Ground data communications infrastructure; Exchange of relevant data between CFMU and Airports		Yes	ATSO, AO, APO
Initial Automation of Routine Tasks	Air/Ground Datalink; ADS (optional); Enhanced Mode S	MTCD and problem solving tools, conformance monitoring, Inter-operable FDPs, Adequate flight data for trajectory prediction, Common environment data (EAD + ASM), Available & accurate surveillance data (Mode S enhanced surveillance + enhanced tracking), Air/Ground data communications infrastructure, Ground data communications infrastructure, CPDLC and ADS, A-SMGCS, MET data for improved TP, EAD	Yes	Yes	ATSO, AO
Advanced Arrival Management		Enhanced FDPS inter-operability; Ground data communications infrastructure		Yes	ATSO
Departure Management (runway sequencing and ground movement part)	A-G Datalink	DMAN tools; Air-ground data communications infrastructure	Yes	Implied	ATSO, AO, APO
Enhanced Safety Net Capabilities	More accurate and dynamic surveillance data	Safety nets (STCA/MSAW/APW), more accurate and dynamic surveillance data	Yes	Yes	ATSO, AO
Air/ Ground data link communication	Air/Ground Datalink	CPDLC, Departure Clearance & ATIS message applications, Air/Ground data communications infrastructure	Yes	Implied	ATSO, AO, APO
Improvements of airport surface movements, planning/routing, guidance and control	ADS-B, Cockpit HMI	Improved surveillance and conflict alert systems, airport datalink systems, ADS-B, airport data communications infrastructure	Yes	Yes	ATSO, AO, APO
Runway & CFMU Slot Integration		Enhanced FDPS, Information management support system, CDM, Ground data communications infrastructure		Yes	ATSO, AO, APO
Initial Increase in Airport Capacity	MMR, Air-Ground Datalink	CDM/planning, AMAN/DMAN, Precision landing aids	Yes	Yes	ATSO, AO, APO
Local weather measurements		Air-Ground communications infrastructure, Optimised airport Met. system for local, weather measurement	Yes	Implied	ATSO, AO, APO

Table 2b: Illustration of ATM 2000+ Initiatives 2005-2009

Operational Improvements	AO/Airborne Enablers	ATM/APO Ground Enablers	A-G Data-link	G-G Data Comms	Stake-holders
Extension of Free Routes	Avionics enhancements, A-G Datalink	Collaborative flight planning, CDM, Dynamic environment data management, Dynamic MET information, Air/Ground data communications infrastructure, EAD	Yes	Yes	ATSO, AO
Optimisation of TMA Airspace and Arrival & Departure Routes		Enhanced ATC tools			ATSO, AO
Collaborative (Civil-Military) National Airspace Planning		Advanced airspace management co-ordination tools, Dynamic environment data management		Yes	ATSO
Collaborative Flight Planning	A-G Datalink	Integration of ATC, ASM & ATFM information, Extended interconnection of computer systems (AOC, Airports, ATM), Data exchange with external areas, Air/Ground data communications infrastructure	Yes	Yes	ATSO, AO, APO
Initial Capacity Management		FUA tools, Improved prediction data processing and tools, Enhanced Tactical Flow Management System (ETFMS)		Yes	ATSO, APO
Automated Arrival Sequencing	Air/Ground Data link	CDM, Integration of ATC, Airports and Aircraft Operators planning processes, Ground data communications infrastructure, Air/Ground data communications infrastructure	Yes	Yes	ATSO, AO, APO
Integrated Arrival & Departure Management	Air/Ground Datalink	Integration of ATC, Airports and Aircraft Operators planning processes, Air/Ground data communication infrastructure, Integrated AMAN and DMAN Tools, A-SMGCS	Yes	Yes	ATSO, AO, APO
Initial separation responsibility transfer	ASAS (limited deployment), ADS-B	ADS-B	Yes	Implied	ATSO, AO
A-SMGCS Surveillance & Alert functions	ADS-B	ADS-B, A-SMGCS tools, Improved surveillance & conflict alert systems	Yes	Yes	ATSO, AO, APO
Improved Gate to Gate Management	CDM	Information management support system, Ground data communications infrastructure		Yes	ATSO, AO, APO
Enhanced CFMU Support for Schedule Co-ordinators	CDM	Enhanced information management support system, full integrated systems (airport, en-route, ATFM), Ground data communications infrastructure		Yes	ATSO, AO, APO
Airports Throughput Increase (Phase I)	CDM/planning, Air/Ground data link, Cockpit HMI	GNSS/ EGNOS, datalink, A-SMGCS tools, AMAN/DMAN, Precision landing aids, improved windshear data	Yes	Yes	ATSO, AO, APO
Improved runway all weather operations	MMR	A-SMGCS integrated with AMAN & DMAN, GNSS/ EGNOS		Yes	ATSO, AO, APO

Table 2c: Illustration of ATM 2000+ Initiatives 2010-2015

Operational Improvements	AO/Airborne Enablers	ATM/APO Ground Enablers	A-G Data-link	G-G Data Comms	Stakeholders
Collaborative European Airspace Planning		Advanced airspace management co-ordination tools, Dynamic environment data management		Yes	ATSO
Fully Flexible Airspace Structure		Advanced airspace management co-ordination tools, Dynamic environment data management		Yes	ATSO
Advanced Tactical ATFM		Integration of Airports, ATC & ATFM information, TACT developments (demand/capacity optimisation), Full Enhanced Tactical Flow Management System (ETFMS), Extended interconnection of computer systems (AOC, Airports, ATM)		Yes	ATSO, AO, APO
Advanced Capacity Management		New/upgraded ATFM tools (incl. FMP), Full Enhanced Tactical Flow Management System (ETFMS), Full integration with TACT and "What If" tools		Yes	ATSO, APO
Enhanced automation of routine planning tasks and redistribution of control tasks (including multi-sector planning)	4D FMS, ADS, Air/Ground Datalink	Integration of ground planning functions, Multi-sector operations & planning tools, 4D Trajectory monitoring tools, 4D FDP tools, Inter-operable FDPs, Dynamic & accurate environment data (EAD + ASM), ADS, Air/Ground data communications infrastructure, A-SMGCS, EAD, Digital AIS by gate link, satellite transmission	Yes	Yes	ATSO, AO, APO
Full Gate to Gate Management of Flight	CDM, Improved navigation capabilities, Air/Ground Datalink	Further integration with airports surface management, ATC, ATFM & AOCs, SMAN, Air/Ground data communication infrastructure, Further integration (airports surface management, ATC, ATFM & AOs), A-SMGCS	Yes	Yes	ATSO, AO, APO
Enhanced Safety Net Capabilities (follow on)	GPWS, More accurate & dynamic surveillance data	Safety nets (STCA/MSAW/APW), More accurate & dynamic surveillance data, safety net tools	Yes	Yes	ATSO, AO
Extended Separation Responsibility	ASAS, ADS-B	Capabilities to support ASAS and to handle contingencies, ADS-B	Yes	Implied	ATSO, AO
A-SMGCS surveillance, alert, planning/routing, guidance and control functions where necessary	ADS-B, Cockpit HMI	Improved surveillance & conflict alert systems, ADS-B, Improved surveillance and conflict alert systems	Yes	Yes	ATSO, AO
Optimised capacity management and best flight profiles, critical aircraft (hub & spokes operations) and critical situations monitoring, real time ATFM	CDM	Enhanced information management support system, full integrated systems (airport, en-route, ATFM), Enhanced information management support system, full integrated systems (airport, en- route, ATFM)		Yes	ATSO, AO, APO
Airports Throughput Increase (Phase II)	CDM, Air/Ground data link, Cockpit HMI, MMR, Wake vortex and windshear detectors,	AMAN/DMAN, Enhanced FDPS, GNSS/ EGNOS, airport surface aspects, datalink, DMAN, CADS, A-SMGCS tools, AMAN/DMAN, Precision landing aids, Wake vortex and wind-shear detectors	Yes	Yes	ATSO, AO, APO
Improved runway and surface management for all weather operations	Cockpit HMI, MMR	GNSS/EGNOS, airport surface aspects, Precision landing aids, satellite navigation	Yes		ATSO, AO, APO

Table 2d: Illustration of ATM 2000+ General Themes throughout the Transition

Operational Initiatives	AO/Airborne Enablers	ATM/APO Ground Enablers	A-G Data-link	G-G Data Comms	Stakeholders
Gate-to-Gate ATM	Air-Ground datalink	Air-Ground datalink, Ground data communications infrastructure	Yes	Yes	ATSO, AO, APO
Collaborative Decision Making	Air-Ground datalink, Ground data communications infrastructure	Air-Ground datalink, Ground data communications infrastructure	Yes	Yes	ATSO, AO, APO
Air-ground Integration	Air-Ground datalink	Air-Ground datalink, Ground data communications infrastructure	Yes	Yes	ATSO, AO, APO
Integration of information systems, ATM-Airline-Airport etc	System-wide information management	AIS/EAD, System-wide information management	Yes	Yes	ATSO, AO, APO
Provision of integrated surveillance and communications systems	CPDLC, Data Link surveillance, Data Link FIS,	Air-Ground datalink, Co-operative ATM Services, ATS/AOC co-operative services	Yes	Yes	ATSO, AO
Re-distribution of Control Tasks	Air-Ground datalink	Air-Ground datalink, Ground data communications infrastructure	Yes	Yes	ATSO, AO

Source: ATM Strategy for 2000+ Volume 2 [15].

The tables clearly demonstrate that the majority of the operational improvements require commensurate enhancements to the aeronautical data communications infrastructure, both ground-ground and air-ground. 38 out of 40 operational improvements listed in tables 1a, 1b and 1c, involve either or both of air-ground and ground-ground data communications enablers. Fully 32 operational improvements require enhancements to ground data communications, while 21 require air-ground datalinks. If one considers that air-ground datalink message traffic must pass through the ground networks, there are an additional five cases where there is an implied involvement of the ground networks, as shown in the tables.

The enhancements that are required to the ground data communications infrastructure involve, inter alia, providing improved connectivity, increased capacity and greater ability to exchange and share information.

The significance of air-ground datalinks for use with ATS messages in the future system is very clear. Such datalinks simply do not exist today (the ACARS datalink used for AOC is deemed unsuitable for the general introduction of ATS message services), yet they are necessary to just over half of the operational improvements, including some in each of the three time periods shown. This means that there is great urgency for initiating the implementation programmes to establish a suitable air-ground communications infrastructure, for without it many of the operational benefits of the Strategy will not be realised.

Those operational initiatives and enablers that implicate communications are at the root of the changing operational requirements for communications services as they evolve over time. Whether upgrades to performance and capability may be achieved by extending or enhancing the existing networks or whether a more strategic approach is necessary, such as that offered by the ATN, is the subject of the following chapters.

It should be noted that the introduction of these communications enablers will have significant implications for both the aircraft cockpit and the ground systems environments of ATSOs, AOs and APOs. The need to make associated changes to the aircraft systems and to the end systems on the ground is one of the reasons why the anticipated

lead times for implementation of enhanced data communications are likely to be quite long.

More specific details of the communications services to be introduced over time are to be found in the ATN Implementation Plan, [123]

2.5 Technical and Non-Operational Requirements for Communications

The preceding sections have focused mainly on the operational needs for enhanced communications, to enable the operational initiatives of ATM, Airlines and Airports to proceed and operational benefits to be delivered.

There is, however, another important set of requirements that has been touched upon in the discussion of integrity, resilience and security, for instance. It relates to the requirements, sometimes termed 'non-operational', that concern the design, acquisition, management, operation and maintenance of the communications infrastructure. The performance of a candidate communications infrastructure in respect of these non-operational requirements can both present technical barriers and have significant cost efficiency implications.

The technical and non-operational requirements for ATM are summarised in Table 3. They are provided in more detail, together with their sources in Annex B, according to the requirement numbers referenced in the Table.

Table 3a: Overview of Technical and Non-operational Requirements

Requirement Category	Consequence of non-compliance
1. TRANSITION	
The ability to integrate new technologies, subnetworks and services and to add capacity as the network evolves whilst retaining full interoperability and seamless service. Req't's: 1,2,19,24,25,33,44,46,47	Inability to extend the functionality or capacity of the networks without service disruption, technology change, network re-design, network replacement and/or network fragmentation, etc
2. SEAMLESS INTEGRATION	
Integrated, seamless end-to-end services with manageability of configuration, standards, performance, integrity, operations, addressing, billing etc., and effective regulation Req't's: 3,5,6,7,45,57	Incompatible standards limit interoperability. Special gateways and interfaces have to be created. Application programming interfaces are not standardised. Addressing may be incompatible and subject to limitations. Multiple billing. All these lead to increased costs of development, acquisition and operations.
3. COMPETITION	
Effective competition in equipment supply and service provision to keep procurement and operating costs down Req't's: 8	Monopoly prices, possibility of less incentive to provide sufficient investment in capacity. Requires a strong regulator.
4. PRIORITY MANAGEMENT	
Ability to prioritise certain types of (typically safety and time critical) message traffic. Req't's: 9,72,74	Either have to segregate priority traffic on a separate network or provide lots of slack capacity to ensure messages get through. Both methods increase costs.
5. GLOBAL INTER-OPERABILITY	
Globally agreed, open standards for equipment, connectivity and protocols Req't's: 10,31	Incompatible regional systems, leading to interoperability problems, need to carry multiple avionics boxes etc. All leading to increased airborne and ground costs.
6. SERVICE DELIVERY	
The capability to provide the necessary range of communications services to defined service levels that satisfy operational requirements. Req't's: 12,16,27,28,29,30,32,43,48,59,62,63,67,68,69	Difficulty in meeting some operational requirements and/or in providing guaranteed end-to-end performance
7. QUALITY OF SERVICE (QoS)	
Provision of sufficient resilience to enable service levels to be maintained under all operating conditions. Req't's: 11,64,73	Cannot accommodate safety-critical or time-critical traffic if QoS is not guaranteed. Either do not put performance critical applications on the networks, have separate dedicated high integrity networks for such traffic, or provide gross over-capacity. All lead to extra costs.
8. POLICY ROUTING	
Control over the types of data communications flowing through any part of the network. Req't's: 14	Inability to segregate or re-route low priority from mission-critical data communications if parts of the network are congested.

Table 3b: Overview of Technical and Non-operational Requirements – continued

Requirement Category	Consequence of non-compliance
9. GATE-TO-GATE COVERAGE	
Seamless integrated communications through all phases of flight Req't's: 15,36,37,43	Fragmented service in fixed and/or mobile communications in some phases of flight
10. GEOGRAPHIC SCOPE	
Integrated communications infrastructure throughout the EUR region Req't's: 11,17	Fragmented service in fixed and/or mobile communications in some parts of the Region
11. COST-EFFECTIVE INFRASTRUCTURE	
Achievement of minimum sustainable costs while meeting the operational and non-operational requirements in full. Economies of Scale, with minimum duplication of development, implementation and operating costs, leading to reduced costs per air movement Req't's: 18,20,21,23,26,35,39,42	Costs in excess of what the minimum sustainable level should be and/or failure to meet requirements in full.
12. SECURITY	
Assurance of Information security and network integrity Req't's: 22,49,50,70	Cannot accommodate secure or mission-critical traffic if security and integrity are not guaranteed. Either do not put critical applications on the networks or implement separate dedicated high integrity networks for such traffic, All lead to extra costs.
13. DIRECTORY AND ADDRESSING	
Provide a common, reliable and extensible addressing scheme. Req't's: 4,38,52	Fragmented addressing schemes, limitations on network scalability, addressing errors.
14. INFRASTRUCTURE MANAGEMENT	
Provide harmonised monitoring and management of the communications infrastructure to ensure QoS and end-to-end performance are achieved Req't's: 13,40,41,65,71	Fragmentation of network management, inability to monitor end-to-end performance, dissimilar levels of monitoring.
15. DELIVERY NOTIFICATION/MESSAGE INTEGRITY	
Provision to ensure the detection and correction of message reception and integrity Req't's: 51,54,58,61	Undetected message delivery failures and/or corruption. Cannot use for mission-critical traffic that would be sensitive to these faults. Alternative is to implement separate high integrity networks for critical traffic, at extra cost.
16. AIR-GROUND DATALINK SELECTION & INITIATION	
Users to be able to select the subnetwork to use and initiate a datalink Req't's: 55,60	Users unable to select their preferred service provider where there is overlapping service coverage. SARPS non-compliance.

2.6 Conclusions on Requirements

Overall, data communications growth in the aeronautical sector is expected to be exponential, with composite growth in air-ground communications of between 2 and 3 orders of magnitude during the period 2000 - 2015. A broadly similar level of growth is also likely in ground-ground data communications. This means that the communications infrastructure as a whole will have to be expanded to have well in excess of 100 times its existing capacity.

The development of future ATM services in Europe is set out in the ATM Strategy for 2000+. This document clearly indicates a dependency relationship between the desired operational improvements, that will deliver operational benefits, and the communications infrastructure as a key enabler of those improvements. It is important to recognise that the strategic direction set out in ATM Strategy for 2000+ is highly dependent on the development of more effective communications between stakeholders and a number of its provisions affect ATSOs, AOs and APOs alike.

Nearly all of the operational improvements foreseen in the Strategy are dependent on ground data communications and just over half require the introduction of air-ground datalink for ATS messages, initially for non-time critical messages and later for time-critical and/or safety critical communications.

However, the communications infrastructure is not just an issue for ATM. The airlines are increasingly reliant upon data networks (air-ground and ground-ground) for their own operations. The amount of datalink traffic for AOC messages is rising rapidly as more aircraft are equipped with datalink and individual aircraft transmit and receive more data. The saturation of the ACARS service, and its general obsolescence, place a strong requirement for a modern replacement. For the airports, there is also a growing dependence on data communications to support integrated airport information systems, wide area communications links and datalinks with aircraft and ground vehicles.

Because the aircraft is the common denominator in all the air-ground datalink applications, there are strong arguments for a common infrastructure to handle AOC and ATS message traffic.

The existing communications infrastructure serving the aeronautical industry is fragmented with a variety of networks of different ages using different technologies, some of them application specific. This situation has two main drawbacks: it is not cost efficient and not ideal, in architectural terms, for providing large scale increases in communications capacity and new applications.

A viable networking solution for aeronautical data communications must meet the operational requirements that stem from the operational improvement initiatives of the stakeholders, only then will operational benefits be delivered.

As a key enabling infrastructure, the communications systems must also meet the technical and non-operational requirements that will ensure that a cost-effective solution is implemented.

These requirements, combined with the exponential data communications growth not only present a challenge to the network designers, implementers and managers, but also mean that most, if not all, of the existing infrastructure will be rendered obsolete.

In short, it is reasonable to expect that the existing network elements will be replaced anyway, so that the argument is not so much about whether to have new networks but is more about defining a scaleable architecture within which these new networks can be integrated.

3. THE CASE FOR A STRATEGIC SOLUTION

This chapter considers the case for a strategic, integrated communications infrastructure covering AO, ATSO and APO requirements for data communications in the period through 2015. The argument presented is independent of any networking architecture and technology.

The comparative feasibility of alternative solutions, namely the ATN and Baseline Scenarios, being able to meet the requirements is assessed in Chapter 4. The cost-effectiveness issues are investigated in Chapter 5.

3.1 Introduction

The proliferation of existing networks and standards, discussed in section 2.1 above, causes expense for the users, yet those in place today will not serve the stakeholders' communications needs in the future. To meet these needs, the existing infrastructure either has to be developed in some way, migrated to a new infrastructure or replaced altogether.

The key question, when considering how to evolve the communications infrastructure to meet the future needs in the short, medium and longer term, is to what extent a radically different approach is either needed or desirable.

Specifically: is a more strategic approach required, to provide a fully integrated, standardised solution for a common infrastructure? The answer to this question requires analysis and is the subject of this chapter. It requires understanding of the differences between strategic and non-strategic approaches and what they can offer.

3.2 Criteria Differentiating Strategic and Non-Strategic Solutions

Before determining what type of solution is required, it is necessary to consider what is meant by the terms 'strategic' and 'non-strategic' solutions.

In essence, a strategic solution is one that is conceived in response to a holistic view of the operational and technical context and requirements which it will have to serve and which makes provision from the outset, within a common architectural blueprint, for changes in context and requirements over time. A 'top-down' process is normally used for developing strategic solutions.

A non-strategic solution, in contrast, does not respond to a holistic view of context and requirements over time but reacts in a piecemeal manner to short term and ad hoc needs as they arise. The process for such developments is often referred to as 'bottom-up'.

Regardless of whether the solution is strategic or non-strategic, 'top-down' or 'bottom up', the process of specification and design is normally iterative and implementation is usually phased and incremental and this should not be confused with the foregoing discussion.

A set of specific attributes of a strategic networking solution are set out in Table 4, together with their non-strategic equivalents.

Table 4: Comparison of Strategic and Non-Strategic Solutions.

STRATEGIC	NON-STRATEGIC
INTEGRATION & COMMON SEAMLESS SERVICES	
Common address management	Addressing limitations for wide area/global use
Transparency of connections	Special gateways and interfaces
Single set of protocols	Multiple, incompatible protocols
Ease of integrating new technologies and applications	Each new technology or application is potentially difficult to integrate and may have to be integrated many times over to different network systems
Open standards, no proprietary technology	May include proprietary technologies
Single point billing possible	Multiple billing unavoidable
Able to handle all types of ATS and AOC message traffic within a single network architecture	Some types of message traffic have to be segregated in different networks to ensure sufficient integrity and performance for critical communications
RESILIENCE	
Architectural approach to end-to-end resilience & redundancy	Resilience provision at local level and comparatively ad hoc
COMPETITION	
Competition and user choice based on service	Monopolies based on technologies & infrastructure
PRIORITISATION	
Architectural approach to end-to-end prioritisation and routing policy	Prioritisation and routing policy local and less comprehensive
GLOBAL STANDARDS	
Common global architecture and standards	Local architectures with gateways
PERFORMANCE	
End-to-end performance monitoring	Only sub-network or link performance monitoring
SECURITY	
Architectural approach to end-to-end security	Security provision at local level and comparatively ad hoc
CAPACITY & SCALABILITY	
Virtually Unlimited Scalability	Limited scalability
Straightforward migration and expansion	Complex migration and expansion
ECONOMICS	
1 set of co-ordinated development activities	Fragmented, duplicated development
Economies of scale	Duplication of costs

3.3 Strategic Communications Capability – is it a Necessity?

There are a number of test questions that will help to resolve the issue of strategic versus non-strategic solutions:

- Could the operational requirements⁵ be met in full without a strategic solution?
- Could the technical and non-operational requirements⁶ be met in full without a strategic solution?
- Would a satisfactory non-strategic solution be found if it only partially met the requirements but had other advantages such as lower cost?

These questions are addressed in the following sub-sections. Note that Table 4, left hand column, defines the capabilities that a strategic solution would exhibit. All these requirements would therefore have to be met for a proposed solution to be deemed strategic.

3.3.1 Could the Operational Requirements be Met in Full without a Strategic Solution?

Operational Requirements in this context are those that relate to the provision of communications services to support specific operational functions of the stakeholders.

The operational needs of the key stakeholders are discussed in section 2.2 above. In addition, the ATM operational initiatives that require communications enablers are analysed in Tables 2a through 2d and discussed in section 2.4.

Meeting these requirements means, inter alia:

1. Greatly increasing the capacity of the aeronautical data communications network;
2. Implementing air-ground datalinks suitable for ATS and AOC applications;
3. Providing guaranteed end-to-end service levels (performance and integrity, etc) for the critical services;
4. Providing connectivity to a greater number of fixed and mobile communicating entities.

In theory, items 1, 2 and 4 might be achieved without recourse to a fully strategic integrated networking approach. However, the need to do this whilst also satisfying item 3 would not be satisfied by a non-strategic approach.

The rationale behind this conclusion is that meeting the operational requirements means that it will be necessary to emulate some, if not all, of the characteristics of a strategic solution. Without this, certain requirements, such as end-to-end performance management, across heterogeneous networks and those carrying mixed types of data traffic, are a questionable proposition. There is a strong link here to the satisfaction of

⁵ i.e. the Operational Requirements that will derive from the initiatives set out in Tables 2a, 2b and 2c

⁶ i.e. the Technical and Non-Operational Requirements that will derive from the categories set out in Table 3 and the requirements listed in Annex B

technical and non-operational requirements addressed in the next section.

The conclusion is that the operational requirements cannot be met in full without a strategic solution.

The feasibility issues in a practical network are discussed in Chapter 4 and under the heading of QoS in Annex C, sections C.2.7 and C.4.7 for the ATN and the Baseline scenarios respectively.

3.3.2 Could the Technical and Non-operational Requirements be Met in Full without a Strategic Solution?

Technical and Non-operational requirements in this context are those that relate to the acquisition, operation and ownership of the communications infrastructure, as opposed to the provision of operational services (see Table 3 and Annex B).

Comparison of Table 4 (strategic and non-strategic requirements) with Table 3 (technical and non-operational requirements) shows that, in every instance, the technical and non-operational requirements match more closely to the strategic than to the non-strategic attributes. Indeed, a solution based largely on the non-strategic attributes shown in Table 4 could not meet the requirements set out in Table 3.

As a consequence, achieving the end-to-end performance requirement, for instance, would almost certainly require critical services to be segregated into dedicated networks, each of which could then be managed like a strategic network.

The conclusion is that a non-strategic solution will not meet the technical and non-operational requirements in full. It would need to put in place additional measures to emulate the features of a strategic solution, with a trade-off against the additional costs of overcoming them, as discussed in section 3.3.3.

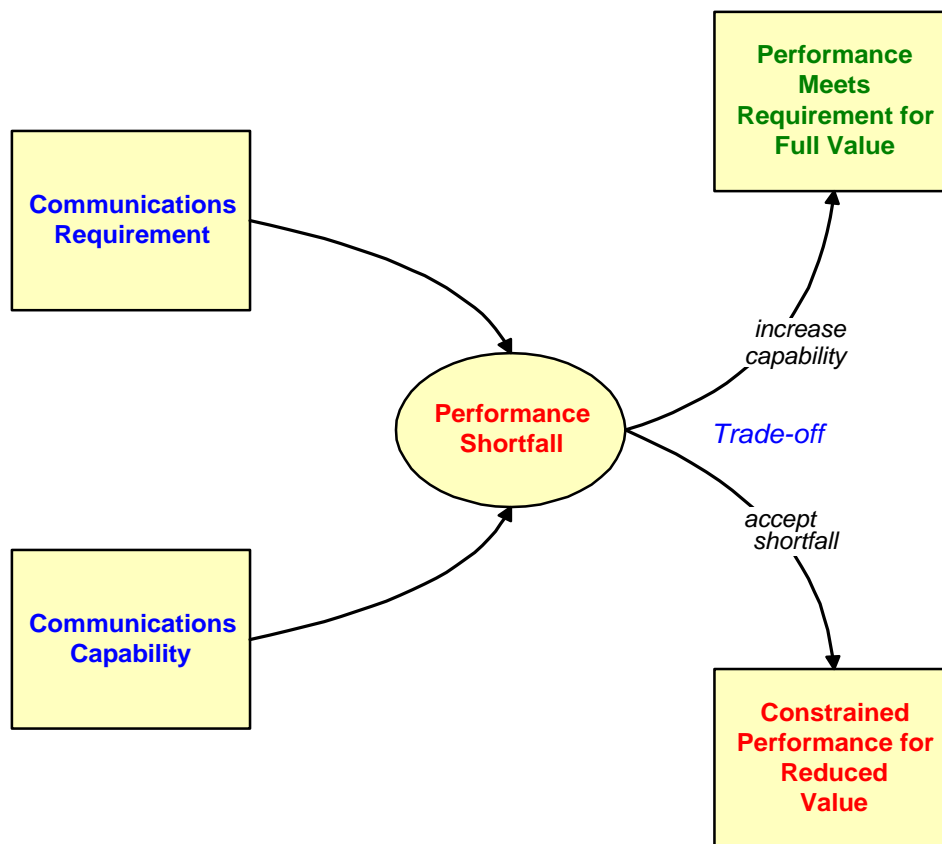
The answer to the question posed above, is that the technical and non-operational requirements could not be met in full without a strategic solution.

3.3.3 Would a Satisfactory Solution be Found if it only Partially Met the Requirements but had other Advantages such as Lower Cost?

Given that it is going to be necessary to develop the communications networks since there is neither the capacity nor the capability in place to meet the predicted communications requirements, something has to be done. The question being addressed here is about how close it is necessary to come to meeting the full set of requirements and hence whether a full strategic solution is needed.

To investigate this question, it is necessary to consider the trade-offs that are implicit in considering anything that is not fully compliant with the requirements. Figure 5, illustrates the choice, in the event of a shortfall of capability, between accepting the shortfall, with a consequent loss of benefit or value, and investing to deliver the capability required.

Figure 5: Decision Choices Concerning Enhancement of the Communications Infrastructure.



In such a situation, it would be necessary to weigh up the potential savings that could be made as a result of not investing, against the business impact of the shortfall. The answer would almost certainly be dependent on the magnitude of the required investment and the size of the cost to the business of the shortfall (equivalent to the value of the potential benefits that would arise from investing to remove the shortfall).

Consideration would also need to be given to the technical and non-operational factors where, in the extreme case, the ongoing cost of enhancing, maintaining and operating obsolete technology could exceed the cost of its replacement. Indeed, it is the technical and non-operational requirements, such as scalability for instance, that may have the greatest influence on the cost-effectiveness of a particular solution.

In practice, the continuing growth in demand for communications capacity will inevitably require that the communications infrastructure is frequently expanded, such that investment will be made under all circumstances. The ease with which capacity may be increased is sure to be an important consideration.

There are thus a number of interrelated factors that have to be taken into account in setting the optimum balance between the rate of investment and the level of shortfall that can be tolerated at any point in time. Sooner or later there is likely to be a 'window of opportunity' where significant change of technology and replacement of infrastructure is needed anyway, in order to maintain service levels. At such times the opportunity arises to move to a different (e.g. strategic) solution for less incremental cost than at other times.

The answer to the question posed in this section is twofold:

- In the short term a trade-off between performance shortfalls and investment costs might be justifiable if the shortfall were small enough not to present significant constraints to the stakeholder's operations. Under these circumstances it might be acceptable to postpone investment although the short term savings might be offset by higher running costs and/or additional costs when upgrading later
- In the longer term, since the shortfall and its business consequences would inevitably tend to get more severe with time as demand grows, only a solution that properly meets the requirements is likely to be acceptable. That is, by definition, a strategic solution.

There is, therefore, a strong argument for moving to a strategic solution at the first window of opportunity.

3.4 Conclusions on the Case for a Strategic Solution

Aeronautical Data Communications is a global market with many stakeholders, a rapidly growing number of new communicating entities (aircraft, operators etc) and a high growth rate in the volume of communications. Against this background, the operational, technical and non-operational communications requirements of the future can only be met in full by a solution that qualifies as 'strategic' against the criteria set out in section 3.2 and Table 4.

The strategic solution must be able to develop and satisfy the capability and performance needs of all stakeholders throughout the period in question. Its ability to consolidate all the data communications needs of the users is critical (e.g. ATS and AOC datalink messages for an aircraft operator; air-ground and ground-ground ATS messages for an ATS provider and so on). Furthermore, the solution chosen must be able to support an incremental migration from existing networks with minimum unnecessary cost and disruption, taking advantage of any windows of opportunity that arise.

The findings of the analysis presented in this section indicate that, in the event that a non-strategic solution is chosen, there would be potentially serious shortfalls in capability and performance, in respect of some requirements. Whilst the shortfalls could in theory be covered by work-arounds, that would incur additional costs. By the time the deficiencies have been corrected it will come to resemble a strategic solution in some criteria whilst remaining ad hoc and inefficient in other ways.

If the shortfalls against operational, technical or non-operational requirements are significant, as they could well be, then a non-strategic solution is unlikely to be economically justifiable. In any case, accepting an increasing shortfall in communications capability and performance will not be acceptable when it starts to seriously constrain air transport operations and when there is no fundamental technological reason for the shortfall.

On the basis of this analysis, there is a strong case for moving to a strategic solution, which meets the criteria set out in Table 4, at the first window of opportunity.

Chapter 4 and Annex C consider, in more detail, the feasibility and relative merits of the ATN and Baseline as candidate solutions for the strategic aeronautical communications requirement.

4. FEASIBILITY OF THE ATN AND BASELINE SCENARIOS

4.1 Introduction

In order to build an argument for the ATN as the most appropriate solution to the future data communications needs of the stakeholders, it is necessary to consider the viability of each of the alternatives. This chapter considers the question of feasibility in relation to the requirements discussed in Chapter 2 and set out in more detail in Annex B. The analysis in Chapter 3 has established that only a 'strategic' solution with the characteristics set out in Table 4 can meet the requirements in full.

There are two candidate scenarios for consideration:

- the ATN that has been defined and developed specifically as a strategic solution
- a 'Baseline' scenario that is based upon the further evolution and development of the existing aeronautical communications infrastructure, the starting point for which is discussed in section 2.1.

For the ATN Scenario, the question is simple: does the ATN meet the intent of its designers in being able to accommodate all the operational, technical and non-operational requirements discussed in Chapter 2? If it does, then by definition it qualifies as a viable strategic solution.

For the Baseline Scenario, the question is: does it come close enough to meeting the requirement to be considered viable as a near-strategic solution and what are the trade-offs that would be involved?

The extent to which the ATN and Baseline alternatives can satisfy these requirements has been assessed and the details are presented in Annex C. This chapter summarises the main points of the assessment.

4.2 The ATN Scenario – 3 Phases of Implementation

The ATN Scenario is set out in full in section 4 of the Proposed ATN Implementation Plan [123]. The implementation is discussed as three distinct phases and these are summarised below.

Phase 1 – Initial ATN Implementation (2000 to 2006) is characterised by autonomous and individual local/regional deployment of ATN systems and initial datalink services (e.g. ACM, CIC) in HTLAs evolving from pre-operational trials and projects (e.g. PETAL-IIe) and deploying first generation ATN routers and end systems (CNS/ATM-1 compliant products). It includes the provision of an air-ground datalink for AOC and ATS functions, making use of VDL Mode 2. This phase supports the European Link 2000+ programme;

Phase 2 – Co-ordinated Trans-National ATN Implementation (2006 to 2012) is characterised by co-ordinated pan-European deployment of both ATN datalink services and ATN ground/ground communication services. This phase supports the provision of area-wide ATN air/ground communication services in HTLAs and most LTLAs in a seamless fashion, the extensive use of ATN-compliant communication services at airports, the interconnection of ATN systems of ATSOs, aircraft operators and airports in the context of integrated information systems and collaborative decision making, the establishment of a fully-fledged European ATN Island Backbone, the upgrade of pan-European ATS systems (e.g. CFMU, EAD) to ATN as well as a major ATN-equipage programme of the European commercial aircraft fleet.

Phase 3 – Full EUR Region ATN Implementation (2012 to 2018) is characterised by area-wide provision of ATN ground and air/ground communication services in the EUR Region, fully operational pan-European ATN systems management (including accounting), and scaling of the European ATN infrastructure into appropriate domains and structures to maintain network efficiency and performance in the large-scale implementation.

4.3 The Baseline Scenario

The Baseline Scenario defines the expected evolution of the aeronautical communication infrastructure in the EUR Region in the event that ATN is not implemented for either air/ground or ground/ground communications. It has been assumed that the communications infrastructure in the Baseline Scenario will be required to support the same operational context in terms of required services as the ATN Scenario. This means that the capability of the technology deployed in the baseline will, in principle, need to meet the same operational, technical and non-operational requirements under each scenario. The Baseline Scenario is set out in detail in Annex C, section C.3 and summarised below.

The air-ground datalink infrastructure is expected to evolve from the existing AOC/ACARS service to incorporate VDL Mode 2, VDL Mode X, AMSS and other datalink technologies, as they become available.

The future ATS ground-ground communications infrastructure will evolve to encompass: an interconnected ATSO X.25 network with a TCP/IP Network Service based on it; various dedicated networks to support the European AIS Database (EAD), radar data distribution, an X.400 Messaging Service, network services dedicated to the CFMU and the CRCO; network management systems for each of the above types of disparate networks based on various industry standards.

Aircraft operators are expected to continue to use the services of communications service providers (e.g. SITA, ARINC) for their wide area data communications requirements and/or continue to use and deploy of various proprietary or standardised networks. Aircraft operators are also expected to make expanding use of the commercial Internet to support their business operations as its capabilities expand. Interconnections with the ATSO and APO related networks will need to be through either standardised or specialised ad-hoc gateways.

Airport operators will continue to deploy standardised or proprietary Local Area Networks to support their operations. Airport requirements for wide area data communications are expected to be serviced through communications service providers (e.g. PTT, ARINC, SITA). Interconnections with the ATSO and AO related networks will need to be through either standardised or specialised ad-hoc gateways.

4.4 Feasibility Summary

The feasibility assessment has been carried out for each scenario in relation to the requirements summarised in Chapter 2 and Annex B. The requirements in Annex B are derived from ATS communications requirements. These are considered to be more stringent than the requirements that aircraft operators and airports would impose for non-ATS applications. A solution that can meet the ATS-derived requirements is therefore deemed to be feasible also for equivalent AOC and airport communications use. The summary results are presented in Tables 6a and 6b below, using the same categories as used in Chapter 2, Tables 3a and 3b.

Table 6a: Summary of the Feasibility Assessment between ATN and the Baseline

ATN FEASIBILITY	BASELINE FEASIBILITY
1. TRANSITION	
Part of the specification is to integrate new higher performance technologies with minimum impact	Multiplicity of networks, applications and interfaces reduces visibility of how transition can be achieved
2. SEAMLESS INTEGRATION	
Designed to provide seamless integrated A/G and G/G networks enabling a "common information pool"	Limited ability to provide seamless integration because of the need to use gateways and address management between networks and systems
3. COMPETITIVE SERVICE PROVISION	
Requirements are based on international communication standards and are specified in ICAO SARPs	Limited possibility of competitive service provision because of existing separate network provider base
4. PRIORITY MANAGEMENT	
Has a comprehensive 16 level priority handling scheme	No end-to-end priority mechanisms are currently defined
5. GLOBAL INTER-OPERABILITY	
Components have been specified in ICAO SARPS enabling world-wide compliance	Gateway functionality is required.
6. SERVICE DELIVERY	
Definition supports, or will support, G/G and A/G broadcast, multicast and "end-to-end" real time services, the aeronautical message handling system, inter-centre co-ordination and context management	Supports G/G and A/G "end-to-end" real time services, limited aeronautical message handling, (potentially) inter-centre co-ordination and context management
7. QUALITY of SERVICE	
Designed to provide a variety of functions to satisfy QoS delivery, management and monitoring requirements	Has limited functions to satisfy QoS delivery, management and monitoring requirements
8. POLICY ROUTING	
SARPs define traffic management based on policy	No defined means by which policy based routing can be achieved
9. GATE TO GATE COVERAGE	
Designed to support "gate-to-gate", pre-flight and post-flight operations	No efficient means by which the "gate-to-gate" concept can be supported

Table 6b: Summary of the Feasibility Assessment between ATN and the Baseline - continued

ATN FEASIBILITY	BASELINE FEASIBILITY
10. GEOGRAPHIC SCOPE	
Standardised internationally for use in the global environment	Capable of providing a uniform service over ECAC/EUR regions
11. COST EFFECTIVE INFRASTRUCTURE	
Cost effectiveness enabled by the specification and design of a common, standardised, scalable infrastructure	Envisaged as a number of separate networks with independent administration and management arrangements
12. SECURITY	
Security features are being designed	No security provisions are currently defined
13. DIRECTORY & ADDRESSING	
SARPs define a comprehensive addressing scheme	Envisaged as each network having unique addressing therefore requires comprehensive address management
14. INFRASTRUCTURE MANAGEMENT	
SARPs are being developed to include comprehensive, operational system management functions	Unable to monitor total infrastructure as single entity
15. DELIVERY NOTIFICATION/MESSAGE INTEGRITY	
Network protocols include delivery and failure notification and recovery functions	Each network will have own specific delivery and recovery mechanisms
16. AIR/GROUND DATA LINK SELECTION & INITIATION	
SARPs include user network selection functions	Selection mechanism is not defined

4.5 Conclusions on the Feasibility of the ATN and Baseline Scenarios

The feasibility assessment has considered the totality of the aeronautical data communications network under each scenario, encompassing air-ground and ground-ground data communications.

4.5.1 Feasibility of the ATN Scenario

The findings of the feasibility assessment show that the ATN based infrastructure should be capable of satisfying, in full, all the requirements as defined in Chapter 2 and Annex B), and will display the attributes of a strategic solution discussed in Chapter 3 and set out in Table 4. The ATN may, therefore, be considered as both technically and operationally

feasible as a strategic solution for the whole of the aeronautical data communications infrastructure. It should be able to provide air-ground datalink services and ground-ground communications in a fully integrated, seamless and effective manner.

4.5.2 Feasibility of the Baseline Scenario

The assessment of the baseline scenario indicates that it will fail to meet the requirements by varying degrees in a number of areas. The significant shortcomings have been identified and, where applicable, Annex C, section C.4 provides an indication of the solutions that would be necessary in order to resolve the shortcomings. In summary, the shortcomings of the Baseline Scenario are likely to be in the areas of:

- the lack of standardisation of application interfaces which hinders network development and capacity enhancement (see C.4.1)
- the need for special purpose gateways and address management arrangements to interconnect dissimilar sub-networks hinders development of seamless operation and provision of a common information pool and raises difficulties for aircraft switching between different air-ground sub-networks (see C.4.2)
- the risk of proprietary solutions preventing proper competition in service provision (see C.4.3)
- lack of effective network-wide priority management (see C.4.4)
- difficulty in achieving global inter-operability between ground systems (see C.4.5)
- lack of defined means for broadcast and multicast communications; no means of describing discrete service levels; no common network infrastructure; lack of data exchange standards and lack of applications that can be shared between stakeholders to implement new concepts such as Collaborative Decision Making (see C.4.6)
- no defined means for policy routing, hindering the use of the networks for mixed types of message traffic (see C.4.8)
- difficulty implementing the Gate-to-Gate concept efficiently (see C.4.9)
- difficulty providing a uniform service over the EUR region (see C.4.10)
- cost inefficiencies (see C.4.11)
- lack of security provisions in the air-ground subnetworks (see C.4.12)
- lack of a common, network-wide, addressing scheme (see C.4.13)
- inability to monitor the end-to-end performance between systems (see C.4.14)
- limitations in delivery notification and message delivery (C.4.15)
- no defined means for users to select the required air-ground datalink (C.4.16)

It is concluded that shortcomings of the baseline are too numerous and significant for it to be regarded a feasible option for satisfying the requirements of the future European aeronautical data communications infrastructure as defined in Chapter 2 and Annex B. Consequently, the Baseline Scenario is also considered unable to meet the criteria for a strategic solution as defined in Chapter 3, Table 4.

5. ATN COSTS AND BENEFITS

5.1 Introduction

Chapters 2 and 3 have demonstrated, in detail, the strategic need for a common aeronautical data communications network in relation to the operational needs of the air transport industry, in particular those arising from the ATM Strategy for 2000+ [15].

Chapter 4 has shown that ATN should be a viable solution to meet the operational, technical and non-operational requirements. In order for the industry to make appropriate investment decisions it will be necessary to demonstrate that ATN provides a cost effective solution as well as being technically and operationally feasible.

This chapter discusses the financial appraisal of the ATN based on consideration of the costs and benefits of its implementation and operation.

The Baseline Scenario is not further considered in this Chapter since it failed to meet the requirements in the feasibility assessment in Chapter 4.

Implementation of the ATN will occur on an incremental, evolutionary basis but, for the purposes of the financial appraisal, can be viewed as having the 3 main phases identified in the Proposed ATN Implementation Plan [123, section 6]. These are summarised in Section 4.2 above.

5.1.1 Background

Work has been in progress since 1998 to investigate the overall Business Case for ATN Implementation in Europe. In parallel, the FAA and C/AFT have been preparing cost benefit analyses to justify initial ATN deployment in the US.

The C/AFT analysis has used statistical techniques to deal with the uncertainty and inaccuracy of the cost and benefit data and, therefore, provides useful pointers for the European financial appraisal. The findings of the C/AFT and FAA analyses are included in the discussion of the Phase 1 ATN implementation in Section 5.2.2 and 5.2.3 respectively.

In October 1998, the FAA Joint Resources Council (JRC) approved funding for the CPDLC Build 1 and Build 1A program. This program comprises the US domestic implementation of ATN over VDL Mode 2 enabling the deployment of (a limited set of) CPDLC services in Miami airspace first (Build 1) and at all US domestic en-route centres in a second step (Build 1A).

5.1.2 Issues

The cost and benefit drivers are to some extent different in each Phase and this issue is discussed in sections 5.2 through 5.4.

Consideration of different stakeholder perspectives is important because they are affected differently by the costs incurred and benefits received and individual stakeholders have their own investment justifications to make. This is also addressed in sections 5.2 through 5.4

The current world-wide lack of reliable quantitative data for operational benefits and a lack of future equipment costs, was discussed in section 1.4.2.3. It has proven to be unrealistic to construct a standard cost/benefit financial case, at this time, using

conventional techniques such as Discounted Cash Flow⁷ (DCF) and Net Present Value⁸ (NPV). The financial appraisal presented in this chapter, therefore, has to remain largely qualitative at this stage. The implications for building a quantified business case and the relevance of the C/AFT approach to the European situation are discussed in section 5.2.4.

5.2 Analysis of Phase 1: Initial ATN Implementation

This section examines the cost and benefit drivers involved in the initial implementation of ATN. The scope of the Phase 1 ATN implementation is described in section 4.2. It supports the Link 2000+ programme and, inter alia, covers the introduction and roll out of specific AOC and ATS functions and limited common services using VDL Mode 2 infrastructure.

5.2.1 Cost and Benefit Drivers

The principal cost and benefit drivers for Phase 1 are summarised in Table 7 for each of the principal stakeholders.

⁷ The year on year presentation of anticipated earnings and expenditure for a potential investment. It is used to determine the year on year rate of return on investment and the payback year (i.e. the year in which the accumulated earnings cover the cost of investment). Money has a time value, i.e. a unit of currency has greater value today than in future years. Earnings and expenditure for future years are calculated, therefore, at present day values using a discount rate based on a number of factors, e.g. investment rates.

⁸ Total earnings (calculated at present day value) less the total expenditure (calculated at present day value) for a given potential investment.

Table 7: Summary of Phase 1 Analysis

STAKEHOLDER	COST DRIVERS	BENEFIT DRIVERS
Airlines	Avionics upgrades* AOC ground host system AOC communications gateways and routers Equipment operating and maintenance costs AOC message costs	Single system for ATC and AOC data communications AOC application use Release of ACARS congestion Delay reduction through increased ATC capacity
ATS Providers	ATN Communications Processor (FEP) and routers etc. Upgrades to ATCO Workstations Upgrades to Data processing systems (FDP) Equipment operating and maintenance costs	Reduced communications workload for controllers leading to capacity increase Reduced cost per controlled air movement
Airport Operators	Not in Phase 1	Not in Phase 1

* There are several foreseeable avionics upgrade scenarios depending on the starting point and chosen transition path. All transition paths start with the implementation of VDL Mode 2. The costs for installing VDL Mode 2 include hardware and cabling costs. Table 8 lists the transition options:

Table 8: Avionics Transition Options

		Forward Fit New Build Aircraft	Retrofit Existing Aircraft Starting From:		
			No datalink	ACARS	AOA
Upgrade To:	AOA	X	X	X	-
	ATN	X	X	X	X

Key: AOA = ACARS Over AVLK

The equipment and installation costs will vary, inter alia, according to the start point and the number of transition steps (typically 1 or 2). Practical upgrade paths, and costs, will

be influenced by the age and avionics configuration of the aircraft being equipped.

It is assumed that VDL Mode 2 ground stations and wide area ground-ground communications links are provided by Aeronautical Communication Service Providers (ACSPs) and paid for via tariffs.

It is further assumed that Airlines will continue to pay for AOC messages while ATS providers will be charged for all ATS messages, which would then be recovered from airlines through normal ATC route charging mechanisms.

5.2.2 The C/AFT Investment Appraisal on Datalink using VDL Mode 2

The CNS/ATM Focused Team (C/AFT) is an airline-driven group, currently chaired by American Airlines. Boeing provides analytical support and acts as secretariat. C/AFT's purpose is to facilitate Communication Navigation Surveillance / Air Traffic Management (CNS/ATM) implementation progress by developing global airline economic consensus on problem issues. C/AFT used a probabilistic economic modelling method to analyse the costs and benefits of equipping aircraft with VDL Mode 2 for AOC and ATC operations. The analysis was performed from an airline perspective, and focused on the value to the airlines of migrating from ACARS to VDL Mode 2 for AOC and ATC communication in a high-density Cruise/Terminal Transition environment of the US National Airspace System (NAS).

The analysis assessed the economic viability of the migration from ACARS to VDL Mode 2 with respect to two benefit drivers. Firstly, there is a growth in demand for ACARS based AOC message traffic, due to new AOC applications, new aircraft entering service and new operators starting to use AOC communications. This will result in increased frequency congestion and non-availability of AOC that would be mitigated by a migration away from ACARS. Secondly, studies [64] show that, with conservative traffic growth projections, traffic delays arising from congestion of US domestic airspace will increase at an accelerating rate and that airline flight schedules will be critically impacted by 2005. Digital datalink is seen as a primary candidate enabler for ATC delay reduction.

Table 9 summarises the investment appraisal results for AOC only, ATC only and Full (both AOC and ATC) message set implementations in relation to forward fit and retrofit of aircraft.

Table 9: Return on Investment for each Scenario

C/AFT ANALYSIS SCENARIO	EXPECTED FINAL % OF EQUIPPED AIRCRAFT ⁹ (Max Equipped Aircraft/Total Aircraft)	EXPECTED NET PRESENT VALUE (\$M)	EXPECTED PRODUCTIVITY ⁷ (Net Expected Benefit /Net Expected Investment)	IRR ¹⁰	BREAKEVEN ¹¹ YEAR (Cumulative Discounted Cash Flow)
Full Datalink	78%	2932	6.3	46%	2008
AOC Only	50%	1019	4.8	41%	2007
ATC Only	78%	824	2.4	24%	2013
Full Datalink for Forward Fit	39%	1000	7.7	57%	2007
Full Datalink for Retro-Fit	39%	1179	3.4	36%	2009
AOC Only for Forward Fit	27%	603	9.2	62%	2006
AOC Only for Retro-Fit	25%	401	2.9	30%	2009
ATC Only for Forward Fit	39%	85	1.6	16%	2018
ATC Only for Retro-Fit	39%	31	1.1	12%	2019

Source: Derived from C/AFT Data Link Investment Analysis Table 6.0-1 [130]

From these results, C/AFT has identified the following headline findings:

- Forward fit equipage of VDL Mode 2 for AOC applications has a **good** return on investment with low risk. The AOC benefits enable airline equipage. The value of maintaining AOC data link capability is one of the primary cost-avoidance drivers. Forward fit equipage should start as soon as possible to avoid the high retrofit costs.

⁹ The final % of equipage is at the end of equipage in the model. The last date for equipage in the model is 2015, but benefits run until 2020.

¹⁰ Internal Rate of Return (IRR) is the discount rate above which an equivalent amount of funds would have to be invested in order to obtain a higher return than that gained from the expected benefits of the project.

¹¹ The year in which the cumulative discounted benefits attributable to the investment become equal to, or greater than, the cumulative discounted costs.

- Forward fit equipage of VDL Mode 2 for Full Data Link has a **reasonable** return on investment with higher risk than the AOC-only scenario. Risks to the airlines associated with investing in ATC data link are mitigated by the need to preserve AOC and the ability to delay additional investment required for ATC benefits until infrastructure and minimum equipage levels are reached. ATC benefits are highly sensitive to uncertainties that cannot be managed, such as overall growth in delays and the proportion of delay reduction that can be apportioned to datalink applications.
- Retrofit equipage will be driven by ATC applications. ATC delay reduction benefits are highly dependent on equipage levels, thus providing an incentive for airlines to retrofit. AOC frequency congestion constraints may be sufficiently alleviated by forward fit equipage, thus providing little incentive to retrofit for AOC benefits.
- Data link equipage for ATC-only has a **poor** return on investment and extends over a long timeframe.

The findings confirm the view that data link is a strategic, long term investment providing a reasonable return on investment, in the context of migrating from ACARS to VDL Mode 2 based AOC and introducing non-time critical ATC applications in the US airspace.

The analysis shows a strong case for the forward fit of AOC datalink improvements. If sufficient numbers of forward fit aircraft adopt VDL Mode 2 for AOC, the resulting reduction in ACARS frequency congestion, coupled with the cost of cockpit upgrades, reduces the economic viability for the retrofit of AOC datalink improvements. The AOC situation, however, may not be the same in Europe and will need to be investigated further to identify the appropriate parameters and values to be used for the Phase 1 ATN Business Case. It is noted that in the US certain AOC applications are used for recording aircraft movements for the purpose of calculating crew remuneration. This is not generally the case in Europe today.

The analysis shows a weaker case for ATC delay reduction benefits. C/AFT extrapolated the FAA Atlanta Study [97] results on delay reduction arising from reduced separation through the use of datalinks. However, the type of benefits claimed will only be available where delays are traceable to sector congestion caused by voice communications workload and where larger than normal separations are the result. It is interesting to note that ATC improvements are cited as the main driver for retrofitting datalink improvements. The US operating environment is different to Europe and, therefore, it is believed the results of the FAA Atlanta Study are not directly applicable. European-specific simulation and operational trial results will be required to provide appropriate parameters and values to be used for the Phase 1 ATN Implementation Business Case.

In summary, the assumptions and parameter values used in the C/AFT analysis are specific to the US context and, therefore, many of them are not directly applicable to the European ATN datalink implementation. The findings are, however, a useful indicator that aircraft equipage for datalink can be shown to be economically viable for airline operators for certain applications.

5.2.3 FAA Investment Appraisal of Datalink

The appraisal was carried out in support of gaining the investment decision from the Joint Resources Council of the FAA, to fund and approve initial builds of the ATN compliant, VDL Mode 2 A/G sub-network based, CPDLC services.

This study highlighted some additional factors that are of potential relevance to the European analysis.

The FAA study concluded that the current ACARS display units, fitted on over 81% of the air carrier fleet and 50% of the regional fleet, would not be suitable for use with CPDLC and that retrofitting new displays would be difficult. Most new aircraft delivered after 2005 are

expected to have appropriate equipment fitted, therefore the FAA concluded that the industry would transition to CPDLC through new aircraft.

Table 10 presents the estimates of the cost of fitting VDL Mode 2 datalink per aircraft, by user type. The left column shows the cost of fitting VDL-2 for AOC and the right column shows the incremental cost of adding CPDLC functions.

Table 10: FAA Cost per Aircraft Analysis

USER TYPE	VDL MODE 2 (\$000's)	ADDITIONAL COST PER A/C OF CPDLC (\$000's)
Airline	97.1	16.6
Regional/ Commercial/ Corporate	54.9	10.9
General Aviation (low end)	13.3	1
Military	54.3	9.2

Source: FAA Datalink Investment Analysis [119]

Ground system costs were excluded in the analysis. ACARS usage costs were assumed to increase by between 3 to 10% per year as an incentive to move to VDL Mode 2. The benefits were based on delay reduction using the FAA Atlanta study [97].

Certification costs were included, based on a 40% take up rate by industry for CPDLC and 60% for VDL Mode 2. Total certification costs for airlines were estimated at \$7.3 million and an additional \$6.9 million for regional airlines.

5.2.4 Applying the C/AFT Investment Appraisal Approaches to the European Context

Given that there is considerable uncertainty about the costs and benefits of datalink, the approach that C/AFT has taken is appropriate since it explicitly models this uncertainty. Confidence in the results of such an analysis should be greater because the output is a probability distribution describing the range of values that NPV might take, rather than a single value. The variables to which NPV is most sensitive are also identified.

The CBA for Phase 1 ATN implementation requires a subset of the data that are needed for the total case covering all three phases.

In order to adapt the C/AFT approach to the European ATN case it will be necessary to review the assumptions and parameters used in the US decision analysis model to ensure they are appropriate in the European context.

5.3 Analysis of Phase 2: Co-ordinated Trans-National ATN Implementation

This section examines the costs and benefits involved in the Phase 2 implementation of ATN.

The scope of the Phase 2 ATN implementation is described in section 4.2 and includes the introduction and roll out of additional sub-networks and applications with extended common services; the introduction of ground to ground networks; and increased geographical coverage of air/ground services. This could include, for example, the introduction of VDL Mode 3 and/or 4 sub-network infrastructures. Phase 2 is also envisaged to encompass the implementation of ATN services to some major airports.

5.3.1 Cost and Benefit Drivers

The principal cost and benefit drivers for Phase 2 are summarised in Table 11 for each of the principal stakeholders. These are in addition to those described for Phase 1.

Table 11: Summary of Phase 2 Analysis

STAKEHOLDER	COST DRIVERS	BENEFIT DRIVERS
Airlines	<p>Additional avionics if multiple A-G sub-networks are required</p> <p>Upgrades to VDL Mode 3 or 4 if one of these replaces VDL Mode 2</p> <p>Air and ground systems costs of adding more AOC applications</p> <p>Airborne costs of adding more ATS applications</p> <p>Increased equipment operating and maintenance costs</p>	<p>Additional AOC benefits</p> <p>Additional delay reduction from ATS applications</p> <p>Benefits from delegated separation responsibility</p> <p>Improved flight profiles from collaborative decision making and ATS applications, e.g. direct routes</p> <p>Better information on inbound aircraft resulting in improved turn-around times for aircraft</p> <p>Increase in spectrum utilisation efficiency through introduction of VDL Mode 3 or 4</p>
ATS Providers	<p>Further upgrades of ground data processing systems and workstations for new applications</p> <p>Upgraded Communications Processors</p> <p>Increased equipment operating and maintenance costs</p> <p>Upgrade of ground network infrastructure</p>	<p>Further increases of ATC capacity</p> <p>Cost avoidance of non-ATN alternatives for communications capacity/performance increase etc.</p> <p>Increased productivity through data link supported collaborative decision making</p> <p>Improved trajectory prediction</p> <p>Improved quality of service</p> <p>Increased productivity from improved ground to ground inter-centre communications</p> <p>Maintained or increased, safety levels</p>
Airport Operators (Major airports only)	<p>Increased equipment operating and maintenance costs</p> <p>Upgrades to Data Processing systems to accept ATN datalink information</p> <p>Upgrades to communication processors and routers to connect to ATN services.</p>	<p>Benefits unclear at this stage, probably include:</p> <p>Improved utilisation of airport resources (airside and groundside)</p> <p>Improved turn-around times for aircraft</p> <p>Improved passenger information systems etc.</p> <p>Improved co-ordination with ATS</p> <p>Improved utilisation/management of airport surface vehicles</p>

The cost and benefit categories presented above emphasise the increased potential of ATN for ground to air data links. The costs and benefits associated with the introduction of ATN ground to ground links are less clear, because, unlike air/ground usage, it is difficult to assess the benefit of migrating to ATN from current ground to ground communication networks on the basis of any individual application.

Common services costs will become significant in this Phase with the introduction of the European ATN Co-ordinating Entity (EACE). EACE will be responsible for the provision of those common ATN services (e.g. European ATN directory server) for which provision by individual parties would be impractical or inefficient (e.g. in terms of administrative/management overhead and assurance of consistency). The benefits associated with common services (e.g. operation of backbone routers, Network Management etc.) are indirect via the operating efficiency of the ATN.

It is assumed that ground stations for Air/Ground communications and wide area ground-ground communications links for airports and airlines are provided by Aeronautical Communication Service Providers and paid for via tariffs.

5.3.2 Issues

The implementation of Phase 2 ATN has the potential to provide a significant benefit gain for all stakeholders through ATC and airline operational communication enhancements and the introduction of airports to the network. It is not possible, however, to quantify the cost and benefit drivers for Phase 2 with any certainty.

More assumptions will need to be made about the environment in which Phase 2 operates. Consideration will have to be given to the possible profiles of benefit gain and investment, for example, Phase 1 ATN-, ACARS- and non-ACARS fitted aircraft moving to Phase 2 ATN will exhibit different benefit gains and upgrade costs. The additional sub-networks in Phase 2 ATN may provide a variety of fit options for aircraft each with a different cost/benefit profile.

5.4 Analysis of Phase 3: Full EUR Region ATN Implementation

The Phase 3 evolution of ATN is described in section 4.2. It will integrate new technologies, such as LEOS/MEOS networks, and have more sub-networks and more applications serving a wider number of stakeholders in a greater number of States. This will result in the availability of an European-wide ATN air/ground and ground/ground communications service enabling enhanced applications that integrate operations of all stakeholders.

5.4.1 Cost and Benefit Drivers

Additional costs and benefits will arise from the introduction of new applications using the ATN infrastructure, and will affect more organisations as the user population increases to cover more airlines, more ATS providers and more airports, operating in more States. The specific categories of cost and benefit drivers are expected to be broadly similar to those described in Table 11, for Phase 2.

The main benefit potential will be to relieve the workload related to routine tasks for all staff, not just pilots and controllers, thereby improving safety, increasing capacity and throughput and improving quality of service provided by the stakeholders to their users. Improved quality and timeliness of information due to the increased connectivity and inter-working will lead to a variety of efficiency gains and some new capabilities. Costs will be incurred for implementing and operating particular applications over specific sub-networks.

Additional benefit gains should result from achieving a critical mass of implementations in

the various application categories. Although this effect should be observable to some extent already in Phase 2, it is in Phase 3 that the full benefit potential of the ATN should be realised.

5.4.2 Issues

The variety of fit and application options relating to services provided over ATN will increase the complexity of the cost benefit analysis.

Not all airline operators, ATS providers and airports will take advantage of all facilities made available over ATN and the financial analysis will need to illustrate the cost benefit profiles according to the different build and application package options.

The incremental benefit and costs will be dependent on the start configurations of the aircraft fleet and these will be more varied than from the start points of Phase 1 and 2.

Consideration will need to be taken on whether there is sufficient data and knowledge of the potential application options, with their associated costs and benefits, to support a meaningful probabilistic analysis at this time. As the costs and benefits become more quantifiable with time then the analysis can be undertaken.

5.5 Conclusions on the Cost-Effectiveness of ATN

The cost/benefit drivers clearly demonstrate the potential of incremental efficiency and effectiveness gains for all stakeholders over the three phases of ATN implementation. In particular, reduction of ATC delays and ATC charges are drivers of the Operational Improvements set out in ATM Strategy for 2000+. Data communications, and in particular air-ground datalink, are enablers for a majority of these improvements.

Phase 1 is the first step in the implementation of ATN and provides the basis on which it will be developed in later phases. Air-ground datalink services are the main source of benefits in Phase 1, and airborne equipage will drive the costs.

The maximum benefit gain is expected to emerge through Phases 2 and 3 as the networks are extended to all stakeholder groups, with a wider set of supported end system applications.

The costs and benefits of aircraft equipage in Phase 1 are dominated by AOC and CPDLC services, reflecting the replacement of the ACARS service and extension of air ground datalinks to include ATS applications.

In addition, commercial airlines are seeking to improve the efficiency of their operations for which AOC datalink is a key enabler. Convergent technologies and the need to minimise costs provide a powerful incentive for a common infrastructure to enable air-ground datalink services for AOC and ATS communications.

The result of a C/AFT analysis, for the USA, supports the view that the introduction of VDL Mode 2 based datalink services provides sufficient ATC and AOC benefits to provide a strategic long term investment with reasonable return [130].

The C/AFT analysis also highlights the differences in cost/benefit drivers for forward and retrofit fleet equipage programmes. The analysis concludes that forward fit equipage of AOC applications is low risk with a good return on investment whilst retrofit equipage is driven by ATC applications that should provide delay reduction benefits to offset high installation costs. The AOC situation, however, may not be the same in Europe and will need to be investigated further.

The FAA's analysis indicates that cockpit HMI issues present an obstacle to the retrofit of CPDLC functions in aircraft. This needs to be explored further in the context of

determining viable transition paths and their associated costs. The analysis also provides an estimate of the cost of certifying airborne datalink equipment that will also need to be taken into account in the European business cases for ATN and Link 2000+.

Full user exploitation of major benefits is dependent upon the co-ordinated introduction of all the relevant technical enablers, of which datalink is one. Additionally, stakeholder groups will seek to offset ATN costs through co-ordinating implementation with already planned developments, such as major fleet purchases and upgrade programmes, introduction of 8.33 kHz in Europe, major ATC system replacements, fleet-wide introduction of AOC, re-organisation of frequency allocations, regulatory changes etc. These represent windows of opportunity for ATN.

The main issue is the lack of available cost/benefit data, therefore, further quantification is required to fully justify investment in ATN. The assumptions used to build the European Business Case will need to be clearly stated and refined over time. Simulation programmes and operational trials, such as PETAL IIe, will provide useful data that is needed to calibrate and verify the quantitative assumptions and parameters used.

Given the complex, 'many-to-many' relationships between operational improvements and their enablers, there is a potential for double counting operational benefits. This applies particularly where there are multiple enablers of an operational benefit (only one of which is communications) but where all enablers must be implemented before the benefit potential can be realised. When developing the detailed, quantified business cases for implementing elements of the future communications infrastructure, it will be important to recognise and avoid such double counting.

6. STAKEHOLDER INCENTIVES

6.1 Introduction

The implementation of the ATN and datalink services requires the synchronised participation of many stakeholders. Their active involvement and participation can be achieved by ensuring that incentives are a key component of a Business Case on which investment decisions are taken.

Different stakeholders will have different incentives for adopting ATN, or otherwise. It is therefore necessary to consider the specific situation of each main group of stakeholders, to ensure that there are incentives that will be a positive influence for the adoption of ATN.

This chapter discusses and recommends an approach for using incentives. It focuses particularly on incentives for the adoption of ATN-based air-ground datalink, since that is the main source of benefits during Phase 1 of the implementation.

6.2 European Context

Incentives are highly influenced by the environment and context in which they have to be used.

An important business characteristic in the European context is the Route Charging System. This system ensures that those who make use of the services pay the cost of providing Air Traffic Services.

In Europe, aircraft operators pay user charges for received air traffic services. The user charges are based on the unit rates and the number of service units (related to the Maximum take off weight (Mtow) of the a/c and the distance flown).

The unit rates are calculated by dividing the cost base by the forecasted number of service units. For a flight, the number of service units is calculated using the following formula:

$$\text{No. of Service Units} = \text{Distance Flown (km)} / 100 * \text{Square root of (Mtow/50)}$$

The cost base used to calculate the unit rate is established every year for each member State. It is composed of investments and operating costs. Investments include the depreciation and interest costs from the date the investment has become operational. For buildings a depreciation period of 20 years is used whereas for equipment the depreciation period is 8 years. The interest rate is fixed every year. Also included in the cost-base is each State's share of EUROCONTROL's costs and, for the four Maastricht States, the Maastricht UAC Centre costs.

The Air Traffic Service Provider stakeholder group consists of organisations ranging from those that are fully state owned to those that have been commercialised. This situation has an influence on the effectiveness of incentives.

Airspace users are a diverse group of stakeholders ranging from operators of leisure aircraft to the major carriers. There are substantial differences between the type and effectiveness of incentives within each category of stakeholders. Within the group of commercial airlines there are also significant differences between the regional and short haul airlines and the airlines with intercontinental operations. Moreover, there are airlines with no AOC datalink history and others that consider the use of AOC datalink as an indispensable aspect of their operations.

There is growing competition between Airport Operators. Like Air Traffic Service

Providers, Airports are either State owned or in private hands, or a combination of these regimes. Competition forces operators to concentrate on costs and services. Most airports have to operate within environmental limits set by the governments. This has an impact on the applicability of incentives.

6.3 Types of Incentives

For incentives to be effective, they have to be, as much as possible, immediate and exclusive. An immediate incentive results in direct near term benefits and, therefore, in direct near term recovery of the investment. For most stakeholders the competitive (relative) market position is more important than the absolute market position. An exclusive incentive ensures that only those who make the investment are rewarded. Investments related to AOC meet that requirement. However, for ATM improvements this criterion is much more difficult to achieve if no use can be made of commercial mechanisms like, for example, differential route charging.

Incentives can be direct or indirect. For example, a discount is a direct financial incentive whereas an operational incentive (advantage) may result in an indirect financial incentive.

The following direct incentives are potentially applicable for the ATN Business Case:

- Strategic incentives
- Operational incentives
- Financial incentives
- Implementation directives.

6.3.1 Strategic incentives

The strategic incentive is a collective incentive, applicable to all stakeholders, and therefore provides non-exclusive benefits. The strategic role of datalink is to enable key operational improvements that are needed to support the expansion of aviation into the next century.

The US C/AFT analysis [130] concluded that datalink (based on VDL Mode 2) should be considered as a strategic long-term investment. The analysis showed the earliest breakeven point occurs in about 7 years for AOC applications usage and 8 years for joint AOC/ATC applications usage. Furthermore, the analysis concluded that investment now will avoid severe problems of AOC non-availability and ATC capacity saturation in 5 years time.

When the airspace system is close to its capacity limits, the delay will increase exponentially with demand to a point where the system is completely saturated. The value of avoiding this situation is almost equivalent to the value of the difference between flying and not flying. Datalink is seen as one of the key enablers for the implementation of ATM measures targeted at avoiding this situation.

The deployment of datalink services on an airspace-wide scale and for all users requires a long time. 5 to 10 years is not an unreasonable estimate for this. When severe ATM capacity constraints are expected in 5 to 10 years it implies that preparatory deployments (e.g. datalink) need to start as soon as possible.

The strategic incentive for datalink is recognised by all stakeholders. However the effectiveness of the incentive is currently low for the following main reasons:

- 5 to 10 years is long term and often 'beyond the business planning horizon'

- As far as ATM is concerned the benefits are not yet exclusive and are not immediate. This encourages a “wait and see” attitude.
- The longer term use of datalink requires more definition and research and development to demonstrate and market the performance improvements.

The effectiveness of this incentive can be increased by providing a better quantitative understanding of the performance evolution of the European ATM system, in terms of demand versus delivery capability and the resulting need for, and timing of, Operational Improvements requiring datalink.

6.3.2 Operational Incentives

Operational incentive measures can be used and are effective but are difficult to implement.

They often require segregation of airspace and/or traffic and are also linked to mandatory equipage. It is not considered feasible to operationally differentiate datalink and non-datalink traffic within a given airspace or centre.

It is assumed that datalink and non-datalink aircraft make use of the same airspace and receive the same services. The only difference will be the means of communication. A communication workload reduction leading to increased ATC capacity, as a result of the use of datalink, will imply a benefit for all airspace users and is therefore a non-exclusive incentive. Indeed, the C/AFT analysis assumed that ATC benefits would apply to all airspace users, irrespective of whether they had equipped with VDL Mode 2 based datalink or not.

There is an incentive in capacity constrained airspace to implement datalink. Main users of such airspace will support the implementation of datalink even when the benefits are non-exclusive. However, when a large population of airspace users is equipped with datalink and the capacity constraint has disappeared, the incentive to equip will disappear. The implication of this is that operational procedures and systems will still have to be based on non-datalink aircraft. There are two major disadvantages related to such a situation. Firstly, no new datalink-based operational procedures can be introduced until all airspace users support datalink. Secondly, the costs of maintaining old systems and procedures, including training, have to be carried by all airspace users.

To avoid this self-constraining situation described, it is necessary to implement measures that guarantee a deterministic implementation, i.e. a clear date by which all aircraft are equipped (see 6.3.4 below). Of course such measures can only be taken when the implementation of the ground infrastructure for datalink has been completed.

6.3.3 Financial Incentives

Financial incentives can be made immediate and exclusive and are therefore effective.

This type of incentive is already being used in the US to stimulate the migration from ACARS to VDL-2, for AOC, by setting ACARS tariffs higher than those for VDL.

Moreover, airlines in the US see a financial incentive in the continued availability of the AOC services that can be achieved by migration to VDL Mode 2, thereby overcoming ACARS frequency congestion. The use of commercial mechanisms to create financial incentives for airlines is, therefore, effective for the AOC use of datalink.

For airline operator use of ATM applications, for which additional investments need to be justified, effective financial incentives are more difficult to implement. The main reason for this lies in the current mechanisms used in Europe to calculate en-route ATM service charges, which have no provision to take account of aircraft equipage and are, therefore,

non-exclusive. Consideration should be given as to how a differential charging structure could be introduced to provide an immediate, exclusive, financial incentive that favours datalink equipped aircraft.

The potential for market-based financial incentives for Air Traffic Service Providers is unclear at present. The main reason for this is the inability, under the current cost recovery regime of the European ATM Route Charging System, to provide an incentive. It is expected, however, that the ATS Provider environment will become more competitive and it can already be seen that commercialised providers are beginning to respond to airspace user demands to maximise performance and reduce unit rates. Datalink services are identified as a key enabler to meet these demands.

In the longer term there may also be market-based financial incentives for airport operators to provide mobile datalink services as part of a total service package to attract new and retain current customers.

6.3.4 Implementation Directives

An implementation directive (mandatory equipage) should only be used if it serves an overall benefit. This mechanism can be used to force aircraft operators, that otherwise benefit from investments made by others, to equip. The timing of mandatory equipage is important, for example, if it is set too early a higher proportion of retrofits will be required and, as a consequence, implementation costs will increase.

An operational advantage of mandatory equipage is that a clear deterministic operational scenario can be developed in which, following a certain date, all aircraft will be able to support the new environment.

The decision to make datalink services mandatory can be taken through a European Notice of Proposed Rule Making (ENPRM) process that is currently being developed. This approach should result in a decision that is supported by a majority of stakeholders. Industry will respond to these decisions by offering equipment and solutions with the advantage of economies of scale.

6.4 Conclusions on Incentives

Incentives should be applied when and where they have an effect, and the incentives most likely to be effective are those which are immediate and exclusive. For the introduction of datalink in Europe three types of incentives can be considered.

A Strategic incentive reinforces a need and helps to provide a 'pull' in the desired direction and thereby encourages early adoption. It is consequently most effective at the beginning of the implementation when it can reduce the lead time needed to start the implementation roll-out. In the present case it has to provide compelling evidence to all stakeholder groups that it is their collective responsibility to enable the necessary future ATM system improvements by investing in datalink. To convince them, it will be necessary to further quantify the strategic arguments that are currently being used in the strategic business analysis.

A financial incentive focussed on the aircraft operators is already being applied for the migration from ACARS to VDL-2 based AOC in the US.

In the longer term there may also be an incentive for airport operators to provide mobile datalink services as part of a total service package to attract new and keep current customers. These incentives are market driven.

Besides the strategic incentive, there is currently no direct financial incentive for aircraft operators to equip for ATC purposes. Initiatives should be undertaken to investigate the possibility of using a differential route charging policy and system to create appropriate

financial incentives.

In the case of ATS Providers the opportunities for financial incentive are less clear, given the way that 100% of costs are recovered through the Route Charging System and, as with some airports, there may be regulatory constraints on the return on investment that is permitted. However, there may be potential for market driven financial incentives to be effective as these organisations become more commercial and competitive in the future.

Implementation directives apply, in principle, to all stakeholders. They will have to be used to ensure fair competition and a clearly defined end date of the migration to datalink, although this end date will probably be different for different classes of airspace. Implementation directives should be prepared through the European Notice of Proposed Rulemaking process and should be initiated as soon as sufficient information is available.

7. CONCLUSIONS AND RECOMMENDATIONS

The strategic business analysis for ATN has reached a number of conclusions, from which some important recommendations can be drawn. The sections below summarise the overall conclusion and the specific conclusions from each chapter of this document, with the conclusions of the Task Force shown in boxes. Following this, the recommendations of the Task Force are presented as a group.

7.1 Overall Conclusion

Providing sufficient ATM capacity to reduce current delays and handle further traffic growth over the next 10 years is a primary concern addressed by the ATM 2000+ Strategy and development of the enabling data communications infrastructure forms a vital component of it.

Overall, the Task Force has concluded that achievement of the operational improvements, that have been identified in the ATM Strategy for 2000+ to be necessary, will be highly dependent upon the timely availability of commensurate improvements to the supporting ATM systems infrastructure. Among the latter, communications services, and in particular air-ground datalink services, are crucial elements that are implicated in the majority of operational improvements.

7.2 The Need for Enhanced Aeronautical Data Communications

Operational benefits will only be delivered by a viable networking solution for aeronautical data communications that meets the operational requirements that stem from the operational improvement initiatives of the stakeholders.

The communications systems must also meet the non-operational requirements that will ensure that a cost-effective solution is implemented.

The existing communications infrastructure serving the aeronautical industry is fragmented with a variety of networks of different ages using different technologies, some of them application specific. Case by case, isolated network development and expansion may seem to be cost effective, however, it is counter-productive when considering a strategic Europe-wide solution. Furthermore, piecemeal development is not ideal, in architectural terms, for providing large scale increases in communications capacity and new applications.

The development of future ATM services in Europe is set out in the ATM Strategy for 2000+, which clearly shows a dependency between the desired operational improvements and the communications infrastructure as a key enabler of them. It is important to recognise that the strategic direction set out in the Strategy is highly dependent on the development of more effective communications between all of the main stakeholders, especially including the introduction of air-ground datalink services for ATS applications.

However, the communications infrastructure is not just an issue for ATM. The airlines are increasingly reliant upon data networks (air-ground and ground-ground) for their own operations. The amount of datalink traffic for AOC messages is rising rapidly, more aircraft are equipped with datalink and individual aircraft transmit and receive more data. The saturation of the ACARS service, and its general obsolescence, place a strong requirement for a modern replacement. For the airports, there is also a growing dependence on data communications.

Given the need to introduce ATS datalink services and to upgrade the AOC datalink, there are strong arguments in favour of a common infrastructure and a single set of avionics to handle AOC and ATS message traffic.

Overall, data communications growth in the aeronautical sector is expected to be exponential, which not only presents a challenge to the network designers, implementers and managers, but also means that much of the existing infrastructure will be rendered obsolete during this period. It is reasonable to expect that the existing network elements will be replaced anyway, so that the argument is not so much about whether to have new networks but is more about the best way to design them and the technologies to adopt.

The Task Force concludes that the current communications infrastructure must change in order to meet the scale of operational improvements required and the current rate of growth in communication usage.

Furthermore, it is evident that the timescales required to implement the infrastructure improvements are relatively long compared to the planning horizons of the participants and action needs to commence now.

7.3 The Case for a Common Aeronautical Data Communications Network

The requirements could be met by a 'strategic' solution in the form of a strategically conceived, common, standardised and integrated communications infrastructure, serving all aeronautical communications, notably AOC and ATS messages. The alternative 'non-strategic' solution would comprise local, ad-hoc, solutions to specific needs that continues the present fragmentation of data networks.

A key part of the rationale in favour of a strategic solution is that Aeronautical Data Communications is a global market with many stakeholders, a rapidly growing number of new communicating entities (aircraft, operators etc) and a high growth rate in the volume of communications (see Chapter 2, section 2.3.1). It is therefore essential to have a standard solution in order to prevent barriers to growth and usage of digital communications and to keep costs at a sustainable minimum. A strategic solution must be able to develop and satisfy the capability and performance needs of all stakeholders throughout the period in question. Its ability to consolidate all the data communications needs of the users is critical. Furthermore, the solution chosen must be able to support an incremental migration from existing networks with minimum unnecessary cost and disruption.

The findings of the analysis presented in Chapter 3 indicate that many of the operational requirements could, in theory, be served by a non-strategic solution. However, trade-offs would have to be made and are likely to result in additional costs that would be incurred to circumvent any shortcomings. In this case, the greater the practical limitations of a non-strategic solution, the more significant the impact will be on its cost-efficiency. By the time the deficiencies have been corrected with additional cost work-arounds it will come to resemble a strategic solution in some criteria whilst remaining ad hoc and inefficient in other ways. The analysis of technical and non-operational requirements showed clearly that a strategic approach is the only one that is likely to succeed in the longer term.

The Task Force concludes that there is a well founded strategic case for a common, integrated communications infrastructure, of the type represented by the ATN, that is built to internationally agreed standards within a common architectural framework and able to handle both AOC and ATS communications.

Furthermore, it finds that a non-strategic solution, based on a proliferation of dissimilar networks and standards that are separately specified, designed and managed, must be regarded as high risk both in operational terms and in its overall cost-effectiveness, particularly in the medium term.

7.4 Feasibility of the ATN and Baseline Scenarios

The analysis in Chapter 4 indicates that the ATN (as a candidate strategic solution) should meet all foreseen operational and non-operational requirements, due largely to its scalable architecture and other attributes.

The Baseline Scenario would appear to exhibit numerous shortfalls against the requirements that will either limit benefit delivery or require potentially expensive work-arounds. However, it is difficult to make general comparisons with the ATN because there is not a single baseline scenario for the future, in that there are a number of different candidate architectures using a variety of technologies.

The Task Force concludes that the ATN represents a feasible strategic solution that should satisfy the aeronautical data communications needs for the foreseeable future.

At the same time, the Task Force concludes that the Baseline Scenario, as evaluated here, will not be able to meet all the operational and non-operational requirements.

This conclusion, formed on the basis of the analysis presented here, is subject to confirmation using the practical findings that will emerge from the various demonstrations and trials that are in progress or planned.

7.5 ATN Costs and Benefits

The ATN will be implemented in stages. Three phases of implementation, consistent with the proposed ATN Implementation Plan, were analysed from the cost-benefit perspective.

The cost/benefit drivers, as identified in Chapter 5, clearly demonstrate the large potential of incremental efficiency and effectiveness gains for all stakeholders over the three phases of ATN implementation. Air-ground datalink services form the principal benefit driver for Phase 1 and airborne equipage (retrofit and forward fit) will drive the costs. The maximum benefit gain, however, is expected to build up during Phases 2 and 3 when the networks are extended to all stakeholder groups with a wider set of supported end system applications.

The Task Force has identified the cost and benefit drivers of introducing ATN and concludes that the potential benefit builds incrementally, throughout the phased implementation, to significant levels for all stakeholder groups.

It further notes that the cost and benefit drivers are different when considering forward fit and retrofit aircraft equipage.

The single greatest difficulty for the business analysis is the sheer lack of hard numbers - there is little reliable data on operational benefits as well as a high level of uncertainty about the costs of future equipment that is not yet developed. This lack of data has been recognised by other studies.

The Task Force has evaluated the available cost and benefit information and finds that there is a lack of data of sufficient quality to build a fully detailed and credible conventional cost benefit case at this time.

In particular it finds that there is:

- a) A lack of firm information about the prices of ATN products that are not yet in production.**
- b) A shortage of quantitative information about the operational benefits that would be enabled by the introduction of new and improved data communications services.**

In addition it notes that there is:

- c) A potential for double counting operational benefits where there are multiple enablers of an operational benefit (only one of which is communications) but where all enablers must be implemented before the benefit potential can be realised.**

To counter the high levels of uncertainty, C/AFT has developed a probabilistic modelling technique that supports the development of a Business Case for air-ground datalink. The illustrative figures in the C/AFT model give an indication that air ground datalink for AOC and initial CPDLC communications will justify investment. The challenge now is to develop sets of reliable quantitative data and build a proper cost benefit model for Europe.

The Task Force has investigated the C/AFT methodology and the results of the US datalink analysis and concludes that the methodology is sound and adds particular value in its ability to handle uncertainties in the underlying data.

A particular implementation issue that will arise is the question of 'Windows of Opportunity'. The demand for data communications is such that continual enhancements will have to be made to the communications infrastructure. The issue for ATN is to provide sufficient incentives to ensure that when a window of opportunity arises, the decision is taken in favour of ATN.

The Task Force recognises that there will be 'Windows of Opportunity' that will facilitate progress with implementation, such as when major systems upgrades or fleet renewals are taking place. Conversely, there may be situations when progress will be delayed waiting for an implementation opportunity to arise. These Windows of Opportunity will apply to most stakeholders and will tend to occur at different times for different organisations, such that implementation will be staggered.

7.6 Stakeholder Incentives

For incentives to be effective, they have to be, as much as possible, immediate and exclusive. An immediate incentive results in direct near term benefits and, therefore, in direct near term recovery of the investment. An exclusive incentive ensures that only those who make the investment are rewarded.

The Task Force has evaluated the effectiveness of possible incentives to promote the take up of ATN in Europe and finds:

- a) Strategic incentives require a compelling strategic Business Case;**
- b) Financial incentives have potential to be made effective and differential en-route charges could be a powerful incentive;**
- c) Implementation directives could be effective, particularly in maintaining operational improvement target timescales by mandating equipage in the later stages of implementation.**

7.7 Recommendations

The ATN Implementation Task Force has set out its conclusions as summarised in the foregoing sections and makes the following specific recommendations:

- 1. The Task Force, having found that there is a strong strategic argument in favour of the ATN, recommends that the strategic case is endorsed.**
- 2. In common with other organisations working in the same field, the Task Force recognises a severe lack of reliable, quantified cost and benefit source data. It therefore recommends that:**
 - a) The importance of simulations and other actions already being undertaken to obtain improved cost-benefit data are confirmed and reinforced;**
 - b) Initiatives are launched, as may be required, to obtain data of sufficient quality to construct a full cost-benefit assessment of the first phase of ATN-implementation in Europe that would justify stakeholder expenditure and, in particular, support a robust Business Case for Link 2000+;**
 - c) The decision to adopt the C/AFT probabilistic analysis method to support the building of the European ATN Business Cases is endorsed.**
- 3. Based on the need to achieve a critical mass of users as soon as possible, the Task Force recognises that a combination of incentives and mandatory equipage are likely to be required to encourage timely action and adoption of the ATN by stakeholders. It recommends that action is initiated to develop and assess incentive mechanisms that will ensure the success of the implementation, specifically that:**
 - a) The European Notice of Proposed Rule Making procedure is initiated as soon as sufficient information on implementation planning is available, to ensure that the mandating of equipage is supported by a majority of stakeholders;**
 - b) Proposals are developed for a differential Route Charge mechanism, for presentation at ACG.**
- 4. Given the importance of 'Windows of Opportunity', the Task Force recommends that relevant windows of opportunity are identified and exploited in the Link 2000+ implementation programme, also that they are taken into account when formulating incentive mechanisms.**

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Note: The references quoted here are the subset used in preparing this document, and have been taken from the master set of references which is to be found in the Final Report of the ATN Implementation Task Force. The reference numbering used is that from the full set.

GLOSSARY OF ABBREVIATIONS

4DTN	4D Trajectory Negotiation
A/G	Air/Ground
AAAV	Azienda Autonoma di Assistenza al Volo per il Traffico Aereo Generale
AAC	Airline Administrative Communications
ACA	Address Compression Algorithm
ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area Control Centre
ACCESS	ATN Compliant Communications European Strategy Study
ACF	Airport Control Facility
ACG	ATS System Concept Working Group
ACI	ATN Communications Infrastructure
ACL	Altimeter Check Location (ICAO 8400/4)
ACM	ATC Communications Management
ACN	Austrian Communications Network
ACSP	Aeronautical Communications Service Provider
ADAP	Automated Downlink of Airborne Parameters
ADLP	Airborne Data Link Processor
ADNET	Administrative Network
ADS	Automatic Dependent Surveillance
ADS-C	Automatic Dependent Surveillance-Contract
AEEC	Airline Electronic Engineering Committee
Aena	Aeropuertos españoles y Navegación aérea (the Spanish CAA)
AES	Aircraft Earth Station
AES	Airborne Earth Station (AMSS)
AFI	ICAO African Region
AFS	Aeronautical Fixed Service
AFSG	Aeronautical Fixed Services Group
AFTN	Aeronautical Fixed Telecommunication Network
AIDC	Aeronautical Information Data Interchange
AIO	ATN Implementation Objective
AIS	Aeronautical Information Services
AMHS	Aeronautical Message Handling Service
AMS	Aeronautical Mobile Service
AMSS	Aeronautical Mobile Satellite Service
ANC	Air Navigation Commission (ICAO)
ANP	Air Navigation Plan

AO	Aircraft Operator
AOA	ACARS over AVLC
AOC	Aeronautical Operational Communications
APATSI	Airport/Air Traffic System Interface
APC	Aeronautical Public Correspondence
APO	Airport Operator
APR	Aircraft Parameter Reporting
APW	Area Proximity Warning
ASAS	Aircraft Separation Assurance System
ASD	Air Situation Display
ASM	Airspace Management
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATCO	Air Traffic Control Officer
ATFM	Air Traffic Flow Management
ATIF	ATN Trials Infrastructure
ATIS	Automated Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATNI	ATN Implementation
ATNII	ATN Institutional Issues
ATNI-TF	ATN Implementation Task Force
ATNP	ATN Project
ATNSI	ATN Systems Inc. (US)
ATS	Air Traffic Services
ATSC	Air Traffic Services Communications
ATSO	Air Traffic Service Organisation
ATSU	Air Traffic Service Unit
BA	British Airways
BB	Backbone
BIS	Boundary Intermediate System
BT	British Telecom
C/AFT	CNS/ATM Focus Team
CAA	Civil Aviation Authority
CADAG	Communications, Automation and Datalink Applications Group
CADS	Computer-Aided Departure Sequencing
CAERAF	Common American European Reference ATN Facility
CAM	Conflict Alert Message
CAMAL	Comprehensive ATN Manual
CAP	Controller Access Parameters

CAPSIN	CAA Packet Switched Integrated Network
CAR	Circonscription aéronautique régionale
CAUTRA	Coordinateur Automatique du Trafic Aérien
CBA	Cost Benefit Analysis
CBN	Common Backbone Network
CDG	Charles de Gaulle
CDM	Collaborative Decision Making
CDU	Control and Display Unit
CEC	Commission of the European Communities
CFMU	Central Flow Management Unit
CHG	Modification Message
CIC	Clearances and Information Communications
CIDIN	Common ICAO Data Interchange Network
CIP	Convergence and Implementation Programme
CIS	Commonwealth of Independent States
CLM	Clearance Modification Message
CLNP	Connection Less Network Protocol
CLTP	Connectionless Transport Protocol
CM	Context Management
CMU	Communication Management Unit
CNS	Communications, Navigation, Surveillance
COMT	Communications Team (EATCHIP)
COTP	Connection Oriented Transport Protocol
COTRAC	Common Trajectory Co-ordination
CPDLC	Controller Pilot Data Link Communications
CRA	Conflict Resolution Advisory (FAA)
CRCO	Central Route Charge Office
CSP	Common Service Provider
CTS	Conformance Test Suite
DBE	Data Base EUROCONTROL
DCF	Discounted Cash Flow
DCL	Departure Clearance
DEP	Departure Message
DEVNET	Development Network
D-FIS	Data Link Flight Information Services
DFS	Deutsche Flugsicherung
DGAC	Direction Generale de l'Aviation Civile
DLIC	Data Link Initiation Capability
DLTF	Data Link Task Force (IATA)
D-OTIS	Data Link Operational Terminal Information

DPN	Data Packet Network
D-RVR	Data Link Runway Visual Range
DSC	Downstream Clearance
DSP	Datalink Service Provider
DUC	Data Link Initiation Capability
DYNAV	Dynamic Route Availability
EACE	European ATN Co-ordinating Entity
EAD	European AIS Database
EAN	European ATSO Network
EANP	European Air Navigation Plan
EANPG	European Air Navigation Planning Group (ICAO)
EATCHIP	European Air Traffic Control Harmonisation and Implementation Programme
EATMP	European Air Traffic Management Programme
EATMS	European Air Traffic Management System
EATNA	European ATN Administrator
EBAA	European Business Aviation Association
ECAC	European Civil Aviation Conference
ECU	European Currency Unit
EFDP	European Flight Data Processor
ENAV	Italian CAA
ENOC	European Network Operating Concept
ENPRM	European Notice of Proposed Rule Making
EOLIA	European Pre-operational Data Link Applications
ES	End System
EU	European Union
EUR	European
EURO AG-DL	European Air/Ground Data Link
EUROCAE	European Organisation for Civil Aviation Electronics
EUROCONTROL	European Organisation for the Safety of Air Navigation
EuroVDL	European VHF Data Link
FAA	Federal Aviation Administration (US)
FANS	Future Air Navigation System
FANS1/A	Future Air Navigation System Version 1A
FATMI	Finnish Air Traffic Management Integration
FCOT	Future Concept Operation Team (EATCHIP)
FDDI	Fibre-Distributed Data Interface (LAN)
FDPS	Flight Data Processing System
FEP	Front-end Processor
FFM	Free Flight Mode

FFS	Free Flight Airspace
FIR	Flight Information Region
FIS	Flight Information Services
FITAMS	Flight Trials of ATN and multiple Subnetworks
FIWs	Flight Plan Input Workstation
FLIPCY	Flight Plan Consistency
FMP	Flow Management Position
FMS	Flight Management System
FPS	Flight Plan Processing Systems
FUA	Flexible Use of Airspace
GDLP	Ground Data Link Processor (Mode S)
GES	Ground Earth Station (AMSS)
GLONASS	Global Navigation Satellite System
GNS	Global Navigation System
GNSS	Global Navigation Satellite System
GPWS	Ground-Proximity Warning System (avionics)
HF	High Frequencies
HFDL	High Frequency Data Link
HMI	Human Machine Interface
HTLA	High Traffic Level Area
IACSP	International Aeronautical Communications Service Provider
IAGDL	Initial Air/Ground Data Link
IAOPA	International Council of Aircraft Owner and Pilot Association
IATA	International Air Transport Association
IBERPAC	Spanish public packet switching network
ICAO	International Civil Aviation Organisation
ICC	Inter-Centre Communications
IDI	Initial Domain Identifier (ICAO Doc 9578-AN/935)
IDRP	Inter-Domain Routing Protocol (ICAO Doc 9578-AN/935)
IEC	Inter Exchange Carrier
IFALPA	International Federation of Air Line Pilot Association
IFATCA	International Federation of Air Traffic Controllers Association
IFPS	Initial Flight Plan Processing System
IFR	Instrument Flight Rules (ICAO 8400/4)
IGA	International General Aviation (ICAO 8400/4)
INAS	International Air Space System
INTNET	Integration Network for Flight Data Exchange (EUROCONTROL)
IP	Internet Protocol
IPI	Initial Protocol Identifier
IRR	Internal Rate of Return

IS	Intermediate System
ISO	International Standards Organisation
ITU-T	International Telecommunications Union
JAA	Joint Aviation Authority
JRC	Joint Resources Council
KLM	Koninklijke Luchtvaart Maatschappij (NL)
LAAO	Large Aircraft Operator
LAAP	Large Airport
LAN	Local Area Network
LEO	Low Earth Orbit
LGS	Latvijas Gaisa Satiksme (Latvian Air Traffic Services Organisation)
LH	Lufthansa
LTLA	Low Traffic Level Area
LTLA-R	Low Traffic Level Area - Remote
MAAO	Major Aircraft Operator
MAAP	Major Airport
MANs	Multiple Area Network
MAS	Managed Airspace
MCDU	Multifunctional Control Display Unit
MEAO	Medium Aircraft Operator
MEAP	Medium Airport
MEO	Medium Earth Orbit
MET	Meteorological
METAR	Meteorological Aeronautical Report
MIB	Management Information Base
MMR	Multi-mode Radio
MOPS	Minimum Operational Performance Standards
MOTNE	Meteorological Operational Telecommunications Network Europe (ICAO 8400/4)
MSAW	Minimum Safe Altitude Warning
MTA	Message Transfer Agents
MTCD	Medium-Term Conflict Detection
MTOW	Maximum Take-off Weight
NAIS	Norwegian Aeronautical Information System
NAM	North America (ICAO Region)
NAS	National Airspace System (FAA)
NAT	North Atlantic
NATN	National Aeronautical Telecommunication Network
NATS	National Air Traffic Services
NATSPG	North Atlantic System Planning Group (ICAO)

Navcom	Navigation Communication
NEAN	Northern European Aeronautical Network
NEXCOM	Next Generations Communications
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (NL)
NMA	Network Management Agent
NMS	Network Management System
NOTAM	Notice to Airmen
NPV	Net Present Value
NSAP	Network Service Access Point
NSM	Network Service Management (COMT TF)
OACC	Oceanic Area Control Centre
OCD	Operational Concept Document (EATMS)
OCM	Oceanic Clearance
ODIAC	Operational Development of Integrated Air/Ground Data Communication and Surveillance (EATCHIP Subgroup)
ODT	Operational Requirements and Data Processing Team
OED	Operational Environment Definition
OHA	Operational Hazard Assessment
OIG	Office of Inspector General
OLDI	On-line Data Interchange
OPMET	Operational Meteorological Data
OPNET	Operational Network for ATS and System Management
ORD	Operational Requirements Document (ODIAC SG)
OSA	Operational Safety Assessment
PAC	Pre-Activation Message
PATA	Pacific Area Travel Association
PDC	Pre-departure Clearance
PDN	Public Data Network
PDU	Power Distribution Unit, or Power Drive Unit, or Protocol Data Unit (ICAO Doc 9578-AN/935)
PETAL	Preliminary Eurocontrol Test of Air/Ground Data Link
PETAL-IIe	Preliminary Eurocontrol Test of Air/Ground Data Link Extension
PPD	Pilot Preferences Downlink
ProATN	Prototype ATN
PSN	Packet Switching Network
PSTN	Public Switched Telephone Network (w. packet switching)
PTT	Post, Telephone and Telegraph (Administrations of various countries)
QA	Quality Audit
QoS	Quality of Service

R&D	Research and Development
RACF	Research and Development Programme in Advanced Communications Technologies for Europe
RAPNET	Regional ATS Packet Switched Network
RASA	Requirements Analysis and System Architecture (EATCHIP Subgroup)
RCC	Requirements Capture and Consolidation
RD	Routing Domain
RDC	Routing Domain Confederation
REDAN	Air Navigation Data Network
RENAR	Réseau de la Navigation Aérienne
RESEDA	French military X.25 network
RMCDE	Radar Message Conversion and Distribution Equipment
RNAV	Area Navigation
RRI	Router Reference Implementation
RTCA	Radio Technical Commission for Aeronautics
RTT	Radio Telemetry Theodolite
RVSM	Reduced Vertical Separation Minima
SADIS	Satellite Distribution System
SAM	Slot Allocation Message
SAP	System Access Parameters
SAR	Search And Rescue (ICAO 8400/4)
SARPs	Standards and Recommended Practices
SELCAL	Selective Calling System (ICAO 8400/4)
SG	Subgroup
SIGMET	Meteorological message
SITA	Société internationale de télécommunications aéronautiques
SLA	Service Level Agreement
SM	Suspense Message
SMAO	Small Aircraft Operator
SMAP	Small Airport
SMGCS	Surface Movement Guidance and Control System
SMGCS	Surface Movement Guidance and Control System
SNA	Systems Network Architecture
SND CF	Subnetwork Dependent Convergence Facility (ICAO 9578-AN/935)
SSR	Secondary Surveillance Radar (ICAO 8400/4)
STATFOR	Statistic Forecast
STCA	Short Term Conflict Alert (ICAO 9578-AN/935)
STDMA	Self-organising time division multiple access
STNA	Service Technique de la Navigation Aérienne

SVC	Switched Virtual Circuit (X.25)
SYSCO	System Supported Co-ordination
TACT	Tactical Flow Management
TAF	Tactical Aeronautical Forecast
TAR	Trials ATN Router
TCAS	Traffic Alert and Collision-Avoidance System (US)
TCP	Transport Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TEN-T	Trans-European Networks – Transport
TES	Trials End System
TF	Task Force
TIF	Traffic Information
TMA	Terminal Manoeuvring Area
TNP	Telematics Network Protocol
TOR	Terms of Reference
TPCSP	Third Party Communications Service Provider
TRANSPAC	French public X.25 network
TSAP	Transport Service Access Point
TTS	Transaction Tracking System
UAC	Upper Area Centres
UAL	United Airlines
UMAS	Unmanaged airspace
US	United States
VDL	VHF Data Link
VDR	VHF Digital Radio
VHF	Very High Frequencies
WAFC	World Area Forecast Centre (ICAO 8400/4)
WAN	Wide Area Network
WP	Work Package
XF	Exit Flight Level

ANNEX A: ATN OVERVIEW

A1. Introduction

The Aeronautical Telecommunications Network (ATN) is the future ICAO specified data communications network and forms an integral part of the global communications, navigation, and surveillance/air traffic management (CNS/ATM) systems concept. The first stage of this concept is CNS/ATM-1, and it defines six applications and the supporting data communications architecture as a set of Standards and Recommended Practices (SARPs). The core SARPs are contained in Annex 10, with the detailed application and communications service SARPs contained in an appendix to Annex 10.

The ATN will enable ATSOs and aeronautical operating agencies to provide datalink users with a range of datalink services, e.g. 'Pre-Departure Clearance', that will provide a safe and reliable alternative to voice communications. The development of new datalink services will provide additional benefits and flexibility in the ATM system. The datalink services will use the underlying ATN datalink applications, ATN end systems and ATN Internet Communications Service (ICS).

The ATN datalink applications, e.g. ADS, provide the communications functionality in the end systems that support the datalink services. The ATN ICS provides the interconnectivity between the ATN end systems (ES), both mobile (avionics ES) and fixed (ground based ES).

In essence, the ATN is an internetwork that will use the ISO OSI¹² suite of protocols to provide the required interoperability, utilise more efficient bit-oriented protocols and provide for more integrated applications and services. Existing and developing communications networks can be used to support the end to end communication of ATS and AOC data between end systems. The connectivity between the 'individual' networks is provided by ATN routers. Figure A3-1 illustrates the ATN concept.

A2. Components of the ATN

The ATN is dependent upon three functional components.. These are:

1. ATN End Systems (ES) e.g. FIS Server;
2. Subnetworks e.g. X.25 PPSDN (Ground/Ground) and VHF Datalink (Air/Ground);
3. ATN Routers (Intermediate Systems (IS)).

A2.1. ATN End Systems

The ATN End System (ES) contains all seven OSI layers in its protocol stack and one or more end user application processes. This provides the ATN ES with the capability to communicate with other ATN ESs to provide end to end communication services to ATN applications.

A2.2. Subnetworks

A subnetwork is an independent communications network based on a particular communication technology, e.g. X25 or Frame Relay, which is used to physically transfer

¹² ISO have defined a reference model which contains seven layers, each layer having a set of defined requirements, interfaces and supporting protocols.

information between ATN systems. The ATN systems can use the subnetworks to transfer the information between air and ground based end systems.

The air/ground (mobile) subnetworks, e.g. VHF datalink (VDL), can be provided by the ATS provider or a third party service provider. To ensure the interoperability of the mobile subnetworks, ICAO have begun a programme of standardisation¹³. This will ensure the air traffic management benefits of the ATN are realised. Equally, there are ground/ground (fixed) subnetworks available, such as the state owned X.25 packet switching networks (CAPSIN, RENAR and RAPNET, etc.), which can be used to provide connectivity between the ATS centres.

A2.3. ATN Routers

The ATN router is an intermediate system (IS) and contains the lowest three OSI layers in its protocol stack. The router provides the connectivity between the various subnetworks and routes messages across the appropriate subnetworks based on criteria such as route availability and priority.

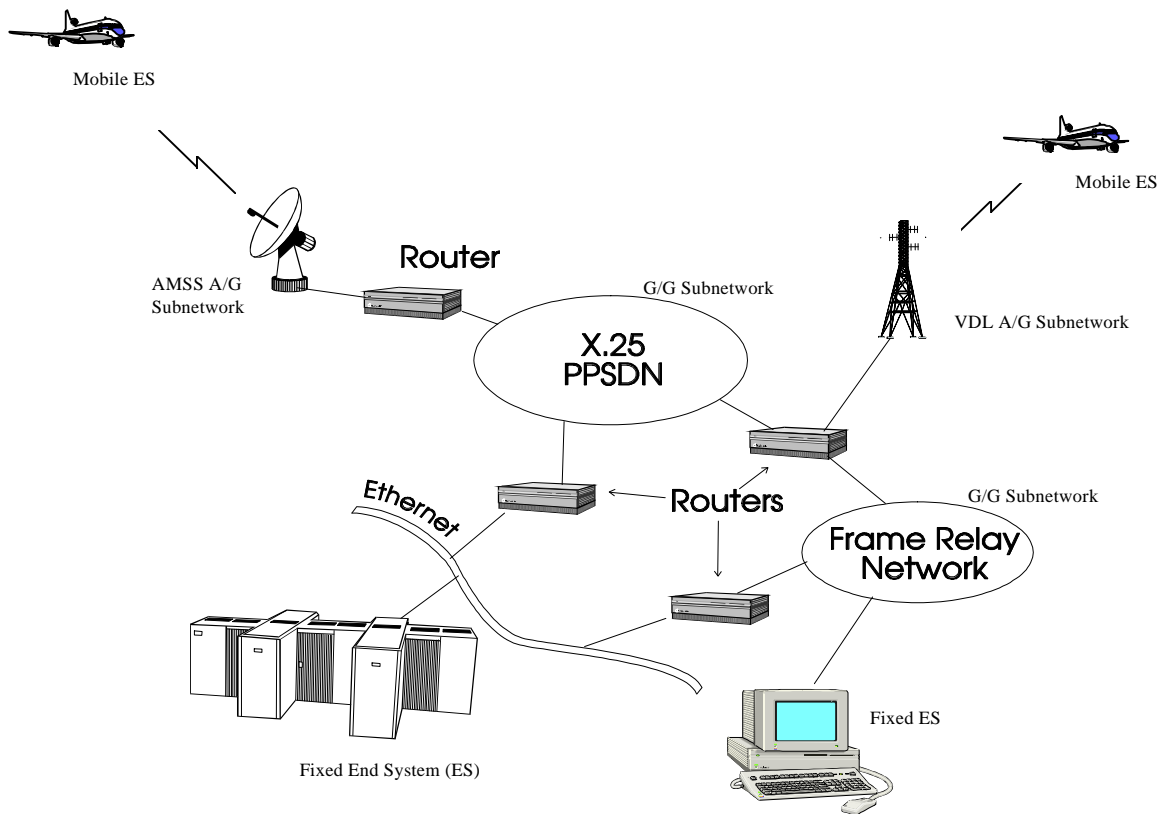


Figure A-1: The ATN Concept

A3. Conclusion

The ATN is a fully scalable network offering prioritised end-to-end communications,

¹³ The SARPs for some air-ground subnetworks are already available e.g. AMSS.

policy based routing procedures and a high service availability to meet the stringent performance and safety requirements needed for ATS. To ensure the ATN can meet present and future demand a range of features including an addressing plan, congestion management and a routing framework have been defined in the ATN SARPs.

In conclusion, the ATN will offer a robust and high integrity communication service between two end systems, either at a fixed location (ATS centre) or mobile (aircraft ES), taking into account the specific requirements of the user.

ANNEX B: COMMUNICATIONS REQUIREMENTS

B.1 Introduction

This chapter presents the requirements on the future European ATS data communications infrastructure against which the ATN and baseline infrastructure alternatives may be objectively assessed. These requirements have been derived from the following sources:

- EATCHIP Communications Strategy (ECS) [1], [2];
- EATCHIP Operational Requirements for Air Traffic Management Air/Ground Data Communications Services (ODIAC-ORD) [21];
- EATMS Operational Concept Document (EOCD) [14];
- ATM Strategy for 2000+ (ATM2000+) [15]
- ATNI Task Force Interim Report (ATNITFIR) [12].

In addition to analysis of these source documents a number of requirements have been developed/derived by the Task Force itself.

Each requirement presented is contributing (directly or indirectly) to one or more of the business drivers for the COM strategy [1], [2] which is reproduced below for ease of reference:

1. **Safety** - *The strategy is to deploy in a timely manner communications services and infrastructure which are reliable, secure and consistent with the new functionality required to support the new operating concepts which are necessary to achieve the overall safety targets.*
2. **Capacity** - *The strategy is to improve use of communications resources and support new operating concepts that are dependent on increased use of data rather than voice, and interoperability between distributed systems components.*
3. **Flight Effectiveness** - *The strategy is to provide improved air-ground communication, and to facilitate ATS/AOC collaboration in flight planning and decision making.*
4. **Cost Effectiveness** - *Business efficiency and airline competitiveness makes it essential that services are provided in the most economic manner. The strategy is that the communications techniques must reflect the best business practices and utilise appropriate technical solutions for best use of resources.*
5. **Environment** - *The strategy is to provide better communications as an enabler to improved flight planning, thereby achieving environmental benefits through improved flight effectiveness.*
6. **National Security** - *The strategy is to ensure interoperability and integration of civil and military ATM while preserving the confidentiality of sensitive data.*
7. **Uniformity** - *The strategy is to ensure that common standards are adopted and implemented globally for aeronautical communications, and to continue the harmonisation and integration of the communications infrastructure throughout the ECAC area.*

B.2 The Communications Requirements

The following table presents an initial list of requirements considered as being applicable to the future European ATS data communications infrastructure. Where a requirement has been derived from a source document it includes (D) in the source column. Where a requirement is reproduced from a source document it includes (R) in the source column.

Ref	Requirement	Source Requirement derived from
1.	The future EUR ATS data communications infrastructure shall facilitate the evolutionary integration of emerging air/ground and ground/ground data communications technology.	Task Force
2.	The future EUR ATS data communications infrastructure shall capitalise on existing communications infrastructure investments made by both air space users and Air Traffic Services Organisations through appropriate coexistence coupled with evolutionary transition plans including the use of gateways.	ECS (D) ATNITFIR (13)
3.	The future EUR ATS data communications infrastructure shall integrate air/ground and ground/ground technology in a seamless manner.	Task Force
4.	The future EUR ATS data communications infrastructure shall support a common and extensible addressing scheme for all air and ground ATS and air space user systems/applications.	Task Force
5.	The future EUR ATS data communications infrastructure shall enable the provision of a common information pool that is available to both air/ground and ground/ground applications in a seamless manner.	Task Force
6.	The future EUR ATS data communications infrastructure shall be transparent to airborne and ground applications/users as they transit from one air/ground subnetwork to the next.	Task Force
7.	The future EUR ATS data communications infrastructure shall at all times, provide an alternate means of air/ground data communications to the a primary means, e.g. SATCOM as a back-up to VDL Mode 2.	Task Force
8.	The future EUR ATS data communications infrastructure shall enable the competitive provision of air/ground and ground/ground services.	Task Force
9.	The future EUR ATS data communications infrastructure shall implement a priority handling scheme that supports a sufficient number of priority levels to distinguish between the various types of ATS and non ATS data and where high priority data is always treated in preference to lower priority data.	Task Force
10.	The future EUR ATS data communications infrastructure shall be based on internationally agreed standards and therefore support global inter-operability.	ECS (D)
11.	The future EUR ATS data communications infrastructure shall satisfy the QoS requirements (e.g. performance, integrity, capacity) for the air/ground and ground/ground applications to support enhanced ATM as defined by the various operational groups/initiatives (i.e. ADSP, ODIAC, ATM 2000+, EATMS Concept and users) for the entire EUR region.	Task Force ATNITFIR (4) ATNITFIR (17) ATNITFIR (12)
12.	The future EUR ATS data communications infrastructure shall be capable of being defined in terms of discrete "service level"	ECS (D)

Ref	Requirement	Source Requirement derived from
	requirements.	
13.	The future EUR ATS data communications infrastructure shall be capable of being monitored and managed to ensure delivery of the required service level (including Quality of Service).	Task Force
14.	The future EUR ATS data communications infrastructure shall enable Users (e.g. ATSOs) to control the type of traffic (e.g. ATS, AOC) transiting their network on a dynamic policy basis.	Task Force
15.	The future EUR ATS data communications infrastructure shall enable the provision of gate-to-gate services/operations including the requirement to address the pre-departure and post-flight phases, and surface movement co-ordination requirements.	ECS (D) ATNITFIR (15)
16.	The future EUR ATS data communications infrastructure shall enable the real time exchange of information between ATSOs, airport operators, aircraft operators and their aircraft to enable enhanced ATM initiatives such as Collaborative Decision and 4-D trajectories negotiation (through connection of the planning systems of airlines to the CFMU).	ECS (D)
17.	The future EUR ATS data communications infrastructure shall eventually enable the provision of a set of communications services that are available in a consistent manner across the EUR Region.	ECS (D)
18.	The future EUR ATS data communications infrastructure shall be capable of providing the required service to all existing and planned ground/ground ATS applications (e.g. OLDI, Met, AIS, CFMU, EGNOS).	Task Force
19.	The future EUR ATS data communications infrastructure shall, as new technology is introduced, be capable of retaining backward compatibility with existing ("legacy") solutions, using gateways where necessary, to allow a planned transition over an agreed period of time.	ECS (D)
20.	The future EUR ATS data communications infrastructure shall, where applicable operational, safety and certification related requirements are satisfied make use of Commercial Off-The-Shelf equipment.	ECS (D)
21.	The future EUR ATS data communications infrastructure shall be such that the use of resources is optimised, e.g. networking in place of point-to-point circuits.	ECS (D)
22.	The future EUR ATS data communications infrastructure shall protect safety-critical ATS & AOC communications from malicious or accidental interference or disruption through implementation of the appropriate security provisions.	ECS (D)
23.	The future EUR ATS data communications infrastructure shall avoid the proliferation of disparate networks, dedicated lines and network/system management systems by providing a common integrated infrastructure to satisfy ALL the aeronautical data communication needs of the ATSOs, Airspace Users (Airline Operational Communications, Airline Administrative Communications and Air Passenger Communications) and supporting entities (e.g. CRCO, AIS, CFMU, EGNOS, Met).	ECS (D) ATNITFIR (3) ATNITFIR (5) ATNITFIR (16)
24.	The future EUR ATS data communications infrastructure shall allow for the continued operation of the Legacy systems by defining "Legacy adaptation interfaces" between them and the new architecture.	ECS (D)

Ref	Requirement	Source Requirement derived from
25.	The future EUR ATS data communications infrastructure shall allow new applications defined with "Standard application" interfaces from the beginning to gradually replace the Legacy units.	ECS (D)
26.	The future EUR ATS data communications infrastructure shall, in order to derive maximum benefit from the underlying data network services, enable the sharing of resources for both operational and administrative data communications purposes.	ECS (D)
27.	The future EUR ATS data communications infrastructure shall include an international Aeronautical Message Handling Service (AMHS), as an X.400 based replacement to the existing AFTN application, which will be phased out of operation from 2004.	ECS (D)
28.	The future EUR ATS data communications infrastructure shall enable the concept of "Collaborative Decision Making" which places increasing emphasis on three-party exchanges, involving pilots, ATSOs and airspace operators.	ECS (D)
29.	<p>The future EUR ATS data communications infrastructure shall provide the following types of communications service in an integrated and transparent manner:</p> <ul style="list-style-type: none"> • ground/ground "end-to-end"; • air/ground "end-to-end"; • ground/air "end-to-end"; • ground/ground broadcast; • ground/ground multicast; • ground/air broadcast; • ground/air multicast; • air/air broadcast; • air/air multicast. 	Task Force
30.	The future EUR ATS data communications infrastructure shall satisfy the emerging communications requirements of the future European Navigation (e.g. EGNOS augmentation systems) and Surveillance infrastructure.	ECS (D)
31.	The future EUR ATS data communications infrastructure shall enable interworking with non-ATSO communications infrastructures (e.g. Search & Rescue) requires the distribution of flight plan information in respect of overdue flights. This distribution may go outside the aeronautical community.	ECS (D)
32.	The future EUR ATS data communications infrastructure shall provide communication services between ATC-centres, and between ATC-centres and aircraft that conform to international standards.	ECS (D)
33.	The future EUR ATS data communications infrastructure shall be capable of handling major (10 fold) increases in both air/ground and ground/ground traffic at relatively short notice.	ECS (D)
34.	The future EUR ATS data communications infrastructure shall not be traffic demand constrained (e.g. as in the case of ACARS in Europe today).	ECS (D)

Ref	Requirement	Source Requirement derived from
35.	The future EUR ATS data communications infrastructure shall permit AOC and possibly APC applications to be carried transparently in conjunction with ATC data communications services.	ECS (D)
36.	The future EUR ATS data communications infrastructure shall enable ground/mobile communication services during the following flight phases: Tactical Planning Phase, Pre-Departure Phase, Departure-Taxi phase, Departure Phase, arrival Phase, Arrival-Taxi Phase, Post Flight Phase.	ECS (D)
37.	The future EUR ATS data communications infrastructure shall enable communications in support of surface movements of other mobiles (not necessarily aircraft, but possibly providing airport services to aircraft).	ECS (D)
38.	The future EUR ATS data communications infrastructure shall provide standardised Directory services to provide users (human or systems) with name to address/number mapping, searching and look-up.	ECS (D)
39.	The future EUR ATS data communications infrastructure shall support the transmission of administrative data, including "real time" Radar and air situation display data, and future multi-media (image/voice/animation/video) data streams, by means of appropriate switching technologies and network services.	ECS (D)
40.	The future EUR ATS data communications infrastructure shall consolidate the currently disparate network and system management technologies to a harmonised distributed, "single image" systems management solution .	ECS (D) ATNITFIR (15)
41.	The future EUR ATS data communications infrastructure shall include a systems management function will be achieved on a distributed basis, with national or regional management centres responsible for specific geographic areas, and an overall co-ordination capability to monitor the end-to-end service characteristics.	ECS (D)
42.	The future EUR ATS data communications infrastructure shall include standardised Applications Programming Interfaces (APIs) to achieve portability and reusability of its components.	ECS (D)
43.	The future EUR ATS data communications infrastructure shall enable co-operation between ATS-providers and airport operators in order to guarantee plan-able punctuality, constant availability of aerodrome and apron control, as well as constant availability of pre-flight information and meteorological services referred to as the "Enhancement of the Tower System" (connection of the operations centres of airports).	ECS (D)
44.	The future EUR ATS data communications infrastructure shall be scaleable in terms of size, connectivity, capacity and QoS support.	ATNITFIR (6)
45.	The future EUR ATS data communications infrastructure shall take into account requirements for mobile data communications.	ATNITFIR (7)
46.	The future EUR ATS data communications infrastructure shall be implemented on an evolutionary incremental basis.	ATNITFIR (9)
47.	The future EUR ATS data communications infrastructure shall enable the provision of additional operational/economical benefits with each incremental implementation step.	ATNITFIR (10)
48.	The data link system shall support the exchange of data between ground and aircraft systems in all airspace types.	ATNITFIR (20) ODIAC-ORD

Ref	Requirement	Source Requirement derived from
.		(FR2)
49.	The data link system shall support distress and emergency functions. This includes a covert capability to deal with acts of unlawful interference.	ATNITFIR (21) ODIAC-ORD (FR6)
50.	The data link system shall provide the capability to unambiguously identify and validate the source and destination end systems for each message transmitted through it.	ATNITFIR (23) ODIAC-ORD (FR9)
51.	The data link system shall have the capability to notify the originator when a transmitted message has not successfully reached its addressee, or has not been responded by the latter within a defined time frame.	ATNITFIR (24) ODIAC-ORD (FR10)
52.	The data link system shall ensure correct addressing of messages.	ATNITFIR (25) ODIAC-ORD (FR11)
53.	A common time reference source shall be used for the synchronisation of the data link end systems.	ATNITFIR (26) ODIAC-ORD (FR12)
54.	The data link system shall reject invalid or corrupted data and allow notification of data to users and data recording.	ATNITFIR (27) ODIAC-ORD (FR14)
55.	The data link system shall provide the users with the capability to manually select available data communications medium when required by operational circumstances (or Quality of Service).	ATNITFIR (28) ODIAC-ORD (FR15)
56.	In the event of link abortion or system shutdown, the ground and the airborne systems support retention of messages.	ATNITFIR (29) ODIAC-ORD (FR16)
57.	The data link system shall adjust to changes in communication media (notably, VHF, Mode-S and Satellite) depending on technical availability.	ATNITFIR (30) ODIAC-ORD (FR18)
58.	The data link system shall provide automatic error checking of user-composed, system-generated, and received messages, as well as informative error messages.	ATNITFIR (31) ODIAC-ORD (FR19)
59.	On initiation and in the event of any subsequent change enable Aircrew and Controllers to identify the data link services available to them and any relevant restriction on their use (e.g. longer than usual message transfer delays).	ATNITFIR (32) ODIAC-ORD (OPR 8)
60.	The establishment of data link for ATS purposes shall only be aircraft initiated. Once the link has been established, the initiation of a specific service or message may be either ground or air initiated. note: This requirement does not exclude that within the mobile subnetwork contact establishment may be ground initiated (e.g. Mode S)	ATNITFIR (36) ODIAC-ORD (OPR 13)
61.	For each received, valid CPDLC data link message , the ground and airborne systems shall transmit a Logical Acknowledgement (LACK)	ATNITFIR (37)

Ref	Requirement	Source Requirement derived from
	to indicate that a message has been successfully received and is operationally acceptable for further processing and eventual display.	ODIAC-ORD (OPR 16)
62.	Aircrew shall have the ability to discontinue one or more Air Traffic Services provided via data link during any phase of flight. Relevant ATSU shall be informed of all Aircrew initiated termination.	ATNITFIR (38) ODIAC-ORD (OPR 17)
63.	ATSUs shall have the ability to discontinue one or more Air Traffic Services provided via data link at any time. Involved Aircrew shall be informed of all ATSU initiated service termination.	ATNITFIR (39) ODIAC-ORD (OPR 18)
64.	Aircrew and Controllers shall be informed of any degradation of the Quality of Service for the data link services they are using. Quality of Service parameters and their required levels are specified in service descriptions.	ATNITFIR (40) ODIAC-ORD (OPR 21)
65.	The data link system shall have the capability to inform its user on its current operational status and configuration (including the status of all automatic functions).	ATNITFIR (42) ODIAC-ORD (HFR11)
66.	The data link system shall provide user access to data link message history.	ATNITFIR (43) ODIAC-ORD (HFR21)
67.	Aircrew shall have the means to monitor and control ATM data link communications to and from the aircraft.	ATNITFIR (45) ODIAC-ORD (HFR27)
68.	The data link applications supported by the aircraft shall be clearly indicated to the Controller.	ATNITFIR (47) ODIAC-ORD (HFR41)
69.	The capability shall be provided to the Controller to select distribution lists defining multiple recipients for the same message (e.g. "turbulence report").	ATNITFIR (48) ODIAC-ORD (HFR42)
70.	The airborne and ground systems shall be able to detect security breaches and alert the users with appropriate data security warnings.	ATNITFIR (57) ODIAC-ORD (SER6)
71.	The data link system design shall ensure that the reliability, availability, continuity and maintainability targets identified as a result of the system safety analysis are met.	ATNITFIR (60) ODIAC-ORD (COMR2)
72.	ATM data communications shall have priority over all other air/ground data communications.	ATNITFIR (61) ODIAC-ORD (COMR3)
73.	The capacity of the data link system shall be such that the Quality of Service for each service is maintained in the case of simultaneous use of all services for all predicted traffic.	ATNITFIR (62) ODIAC-ORD (COMR4)
74.	The future ATS data communications infrastructure shall have the capability to detect and recover from congestion.	Task Force

ANNEX C - FEASIBILITY OF ATN VERSUS THE BASELINE

C.1 Introduction

A set of high level requirements for the future ATS data communications infrastructure has been presented in Chapter 2, Table 3 of the main document and Annex B. The objective of this chapter is to assess the extent to which these requirements may be satisfied by each of the ATN and baseline alternatives. Each section follows the set of requirements categories from Table 3 and the corresponding requirements from Annex B are shown as [REQ n].

Section C.2 discusses the extent and means by which an ATN based infrastructure satisfies the key attributes presented in Table 3. It identifies functionality, additional to that defined today, which would be necessary to be implemented in order to satisfy the key attributes.

Section C.3 presents a description of the most likely alternative evolution of the European ATS data communications infrastructure in the event that the ATN is not implemented.

Section C.4 discusses the extent and means by which a non- ATN based infrastructure is likely to satisfy the key attributes presented in Table 3. It identifies additional functionality, to that defined today, which would be necessary to be implemented in order to satisfy the key attributes.

Section C.5 presents conclusions with respect to the feasibility of each of the ATN and baseline infrastructures to satisfy the key attributes of the future European ATS data communications infrastructure.

C.2 ATN Feasibility

C.2.1 Transition

The ATN has been specified in such a manner that, as new higher performance underlying air/ground and ground/ground technologies emerge, they may be integrated into the overall infrastructure (or replace existing technologies) with minimal impact (if any) on the applications that will make use of the new technologies. [REQ1].

There are currently two main systems that will be replaced:

- AFTN (ground/ground)
- ACARS (air/ground).

For the AFTN, gateways have been specified for transition of the current AFTN environment to the future AHMS environment as specified in the ICAO SARPs [38]. These are referred to as AFTN/AMHS Gateways. For air/ground data communications work is on-going in the AEEC [61] to define a gateway solution for ACARS AOC applications to operate over an ATN compliant infrastructure. [REQ2], [REQ19], [REQ24], [REQ25].

Migration of ACARS AOC applications to the ATN may be facilitated for some airlines by the optional intermediate step of ACARS Over AVL (AOA) using VDL Mode 2 datalink [11]. In due course it is expected that AOC applications will migrate completely from ACARS to ATN, permitting ACARS services to be discontinued.

In addition to the above it is expected that a TCP/IP based data communications system may start to be deployed to support aeronautical services, e.g. flight plan data exchange

[64]. Gateways for TCP/IP to ATN communications may be developed to support migration of these TCP/IP services to an ATN environment. [REQ2].

It is expected that following the successful introduction of initial ATN air/ground and ground/ground services it is likely that (as was the case with the commercial Internet) there will potentially be an exponential increase in demand for both air/ground and ground/ground services. An ATN based infrastructure will be able to satisfy this demand through introduction of additional alternate air/ground and ground/ground links (i.e. provide additional alternate capacity). This additional capacity is introduced with minimal impact on users and/or their applications since its is within the domain of the service provider. Due to the manner in which the ATN routing framework has been defined, an ATN based infrastructure may additionally grow in geographical scope in an evolutionary manner without any architectural constraints. An ATN infrastructure may be, and is expected to be, deployed in an evolutionary incremental manner whereby each increment will enable operational and/or economic benefits.[REQ33], [REQ34], [REQ44], [REQ46], [REQ47].

C.2.2 Seamless Integration

The ATN has been designed to integrate air/ground (e.g. VDL, Mode S, AMSS, HFDL) and ground/ground (e.g. CIDIN, PTT networks, ATSO networks) into a single seamless “internet”. In such an environment the user sees an “internet” service and need only specify the destination name/address and QoS information associated with his message. The user need not be concerned with the actual underlying technology that will be used to relay his message. [REQ3]

Due to the seamless integration of the various air/ground and ground/ground technologies, the ATN enables the provision and establishment of a “common information pool” available to all airborne and ground users alike in a transparent fashion. This in turn will enable the efficient deployment of enhanced ATM concepts such as Collaborative Decision Making (CDM) and Free Flight. [REQ5]

The mechanisms defined for the ATN allow for multiple air/ground routes (i.e. multiple air/ground subnetworks) to be available to user applications at any one time thereby providing redundant coverage in high density areas. Additionally, mechanisms have been defined in the ATN to make transparent, to the mobile and ground users, changes in the use of underlying air/ground subnetworks as mobiles (e.g. aircraft) switch from coverage of one subnetwork type to another (e.g. AMSS to VDL). [REQ6], [REQ7], [REQ57]

C.2.3 Competitive Service Provision

The ATN architecture enables competitive service provision of the underlying air/ground and ground/ground subnetwork services, this being due to the fact that the requirements (from an ATN perspective) for access to these services are based on international communications standards, e.g. X.25 packet layer protocol for air/ground services, X.25 for ground/ground WAN services and Ethernet LAN for local area services and could therefore be provided, in theory, by any telecommunications service provider. For example, an airline may contract service provider “A” to provide all its VDL communications for a certain timeframe. In the mean time another service provider “B” may enter the market and offer a more attractive charging tariff than service provider “A”. In such a situation the airline should be able to switch service providers without any change to its own airborne and ground based communications infrastructure. Due to the fact that the ATN “internet” and “upper layer” services are standardised it will also be possible for the competitive provision of these services by commercial communications service providers and even ATS providers. [REQ8]

Furthermore, the fact that the requirements for the various ATN components have been specified in ICAO SARPs and are based on international ISO standards enables competition in the industry to develop ATN SARPs compliant products.[REQ8]

C.2.4 Priority Management

The ATN SARPs define a comprehensive priority handling scheme that allows the end user to specify one of 16 priority levels. The ATN SARPS require that both End and Intermediate Systems treat any message of a higher priority in preference to relatively lower priority messages. Where the underlying air/ground or ground/ground subnetworks support priority then a mapping is performed between the ATN and underlying supported subnetwork priorities. [REQ9], [REQ72].

The ATN SARPs define mechanisms applicable to ATN End Systems and Intermediate Systems to detect and recover from periods of congestion in the network. [REQ74].

C.2.5 Global Inter-operability

Ensuring global inter-operability between States and between States and aircraft flying anywhere in the world was one of the primary goals of the ATN design and the sole reason for developing ICAO SARPs for the ATN. Numerous and significant validation initiatives have been and are being undertaken by various ICAO States to demonstrate that independent SARPs compliant ground and airborne implementations inter-operate.[REQ10].

Due to the open nature of the ATN (i.e. based on ISO OSI standards) it will be possible for ATN systems to communicate with systems outside the aeronautical domain either directly in the case of ISO OSI systems or indirectly through gateways (e.g. TCP/IP gateways). [REQ31].

C.2.6 Service Delivery

As currently defined, the ATN supports the following types of communications services in an integrated manner:

- ground/ground “end-to-end”;
- air/ground “end-to-end”;
- ground/air “end-to-end”.[REQ29]

Though not supported by the current definition of the ATN work is underway in the ICAO ATNP to specify and validate the appropriate functionality to support:

- ground/ground broadcast;
- ground/ground multicast;
- ground/air broadcast;
- ground/air multicast;
- air/air broadcast;
- air/air multicast.[REQ29]

The ATN communications service has been specified in terms of “class of service” whereby each class is associated with a maximum end-to-end transit delay (95% probability) as indicated in table B-1 below. [REQ12].

Table C-1: ATN End-to-End Transit Delays

Maximum One way ATN End-to-End Transit Delay at 95% probability (seconds)	ATSC Class
Reserved	A
4.5	B
7.2	C
13.5	D
18	E
27	F
50	G
100	H
No value specified	no preference

Services based on concepts such as Collaborative Decision Making (CDM) and 4-D trajectory negotiation require that the relevant information is both accessible by and exchanged between all involved parties (e.g. airport operators, aircraft operators and ATSOs). A common infrastructure based on the ATN will facilitate these types of exchanges between the various parties in a standardised, simple and optimal manner. [REQ16], [REQ28], [REQ43].

The ATN SARPs include the definition of the “Aeronautical Message Handling System” (AMHS) which, based on the CCITT X.400 standard and operating over the ATN internet communications service, has been designed in order to replace the ageing AFTN.[REQ27].

The ATN SARPs define the provisions for the “Inter-Centre Co-ordination” application whose objective is to facilitate the exchange of flight plan related data between ATC centres. The ATN SARPs additionally define the provisions for the following applications for air/ground data exchange which will enable enhanced ATM concepts in all airspace types to be implemented:

- Automatic Dependant Surveillance (ADS);
- Controller Pilot Data Link Communications (CPDLC);
- Flight Information Services (Automated Terminal Information Service) (FIS/ATIS). [REQ32], [REQ48].

An ATN based infrastructure may be designed so that either aircrew and ATSOs are provided with the ability to terminate one or more Air Traffic Services provided by data link. The infrastructure can be designed so that the aircrew are provided with the ability to monitor and control ATM data link communications to and from the aircraft. [REQ62], [REQ63], [REQ67].

The “context management” application defined in the ATN SARPs enables the controller to identify the data link applications supported by the aircraft following the aircraft’s log-on to the ground infrastructure. [REQ68] [REQ59].

An ATN based infrastructure will support delivery of the same message to multiple recipients. [REQ69].

C.2.7 QoS

An ATN based infrastructure will satisfy the QoS requirements through the following means:

- inherent functionality of the ATN protocols, e.g. transport layer check-sum to ensure message integrity;
- appropriate dimensioning of the network to satisfy the forecast traffic demand (e.g. capacity of links);
- optimal design of the routing architecture to ensure availability and rapid convergence/update of route changes (including mobiles);
- priority handling to ensure that highest priority messages are processed with the highest priority;
- congestion management whereby upon automated detection of congestion in the network the network reacts in such a way that congestion is relieved;
- systems management and monitoring on a real time basis to ensure that the required QoS is maintained through provision of short term solutions. [REQ11], [REQ73].

In the event that the QoS supporting a particular ATS service degrades beyond the level required the ATN infrastructure is capable of notifying the controller and aircrew accordingly. [REQ64].

C.2.8 Policy Routing

The ATN SARPs define provisions that allow organisations such as ATSOs to control the type of traffic that transits through their network on a policy basis. For example, during off peak periods an ATSO may wish to make his network available to support administrative communications [REQ14].

C.2.9 Gate to Gate Coverage

An ATN based infrastructure is capable of providing services in support of the “gate-to-gate” concept and will be able to provide services in the pre-flight and post flight phases (via gatelink for example which may be integrated into the ATN infrastructure as a subnetwork or the airport VDL service). The ATN may also be used to provide mobile services to vehicles operating on the airport surface as the SARPs do not distinguish between aircraft and other mobiles such as these vehicles. [REQ15], [REQ36], [REQ37], [REQ43].

C.2.10 Geographic Scope

The ATN has been standardised internationally in order to provide the communications back-bone of the future global Air Traffic Management environment. To that end it is capable of providing a uniform service over the ECAC/EUR regions. [REQ11],[REQ17].

C.2.11 Cost/Effective Infrastructure

The ATN has been specified and designed to satisfy the data communications needs of all organisations involved in the ATM process and the aeronautical industry in general. The ATN design has, in addition to supporting operational communications, taken into account the need to support administrative communications thereby providing a common network infrastructure.

In future, when a full set of ATN products are available, an appropriately dimensioned ATN based data communications infrastructure will be capable of supporting the data communications needs of the entire current ground/ground operational and administrative environment (e.g. CRCO, OLDI, Met, AIS, CFMU) in a standardised and efficient manner and will avoid the on-going inefficiencies involved in maintaining and operating application specific networks and dedicated point-to-point lines.

Due to its scaleable nature an ATN based network may be enhanced to provide additional capacity to meet the requirements of future applications that may emerge, e.g. EGNOS. An ATN based infrastructure may additionally be enhanced to support longer term applications such as multi-media (video, voice, animation) data streams. [REQ23], [REQ18], [REQ30], [REQ39], [REQ21], [REQ26], [REQ35].

The ATN SARPS define standardised application service interfaces in order to ensure portability of applications software from one platform to another thereby significantly contributing to reductions in product costs. [REQ42].

C.2.12 Security

As it was not considered necessary for initial implementations, the current ATN SARPs do not contain specific security mechanisms to guard against potential risks (e.g. masquerade). Such features are currently under development by the ICAO ATN Panel in the frame of "Package 2", i.e. CNS/ATM-2. A security policy for the ATN was endorsed at ATNP/2 [40] that has provided the basis for the development and standardisation of the Package 2 security mechanisms. Should security provisions be needed in the initial implementation then they may be defined and introduced on a regional basis for both air/ground and ground/ground data communications. The approach adopted may be submitted to ICAO as input to the standardisation process. [REQ22], [REQ49], [REQ50], [REQ70].

C.2.13 Directory & Addressing

The ATN SARPs define a comprehensive addressing scheme that is applicable to all airborne and ground systems/applications. The address space allocated is sufficient to support the potentially huge number of systems that may eventually be equipped with ATN. The ATN Panel is currently looking at defining a directory service that will support the mapping between user friendly names allocated to systems and their physical addresses. [REQ4], [REQ38], [REQ52].

C.2.14 Infrastructure Management

Though not yet standardised in ICAO SARPs, a regional ATN-based infrastructure will need to be, and will be capable of, being managed by one or more systems management entities, to ensure that the QoS required of the network on an "end-to-end" basis is maintained. Such a management system will be able to determine the current operational status of all network elements. The ICAO SARPs for the standardisation of the necessary management information and means to access the information are currently under development by the ATN Panel. The methods and means to facilitate management of the infrastructure may be defined and introduced on a regional basis for the initial implementation. The approach adopted may be submitted to ICAO as input to the standardisation process. [REQ13], [REQ40], [REQ41], [REQ65], [REQ71].

C.2.15 Delivery Notification/Message Integrity

The end-to-end transport protocol defined for use in the ATN ensures that the originator of a message is notified in the event that his message is not delivered. The ATN protocols ensure that any corrupted data is identified as such and include mechanisms for re-transmission of data without the need for user intervention. The transport protocol includes an end-to-end Cyclic Redundancy Check (CRC) which ensures an undetected

error rate of better than 1 in 10^{-5} . This coupled with the type of integrity checking one could expect from a typical air/ground subnetwork (1 in 10^{-8}) will result in an overall integrity figure of 1 in 10^{-13} . This exceeds the typical requirement expressed by the ICAO ADS Panel for the applications it has defined, i.e. ADS, CPDLC and FIS. [REQ51], [REQ54].

The ATN CPDLC SARPs contain an optional feature, the "Logical Acknowledgement", (LACK), which provides an indication to the originator of a message that its message has been received and is suitable for display/processing by the recipient. [REQ61].

C.2.16 Air/Ground Data Link Selection & Initiation

The ATN SARPs contain provisions which allow users to select the air/ground subnetwork(s) over which their data link communications should be transmitted, e.g. it is possible for an aircraft to specify that all its data link communications be routed over AMSS only. [REQ55].

The establishment of a "data link" connection between an aircraft and ground ATS system is always aircraft initiated through the use of the context management application as defined in the ATN SARPs.[REQ60].

C.2.17 ATN Feasibility - Conclusion

From the preceding sections it can be concluded that an ATN based infrastructure is capable of satisfying the foreseen operational and non-operational requirements for the future European data communications infrastructure as presented in Chapter 2 and Annex B.

C.3 Baseline Scenario

C.3.1 Definition

The Baseline Scenario defines the expected evolution of the aeronautical communication infrastructure in the EUR Region in the event that ATN is NOT implemented for either air/ground OR ground/ground communications.

C.3.2 Baseline Requirements

It has been assumed that both the infrastructures foreseen for deployment in the baseline scenario and ATN scenarios, respectively, will be required to support the operational context as defined by the operational groups, i.e. ODIAC [21]. This means that the capability of the technology deployed in the baseline will be required to, inter alia, enable the provision of air/ground and ground/ground services defined by ODIAC as within the bounds of the defined performance requirements, e.g. message integrity, end-to-end transit delays etc.

C.3.3 Evolution of Air/Ground Infrastructure

The ATS air/ground infrastructure foreseen for use/deployment in the baseline is considered to be the following:

- ACARS - expected to be used up to 2005 (for non time critical and non-safety applications, i.e. DCL & ATIS)
- VDL Mode 2 ("point-to-point" – - expected to be used from 2005 onwards to replace use of ACARS)

- VDL Mode “X” - expected to be used from 2010 onwards to replace use of VDL Mode 2
- FANS 1/A - expected to be used from 2000 onwards
- AMSS Data 3 (“point-to-point” - expected to be used from 2000 onwards)
- Gatelink - expected to be used from 2000 onwards.

C.3.3.1 ACARS

There has been an explosive demand by AOC applications for the ACARS service since it was introduced in 1978. With respect to ATS applications ACARS has been considered suitable to support non-safety/ critical applications such as Departure Clearance (DCL) and Automated Terminal Information Service (ATIS). However, even with ARINC's recent entry into Europe to provide ACARS services and therefore additional capacity, it is considered that, given forecasted growth in AOC and ATS traffic, the ACARS system will be unable to satisfy the required capacity into the next millennium. It is expected that ACARS will be used for DCL and ATIS services at key airports up to the 2004 timeframe.

C.3.3.2 VDL

Given the foreseen limitation in ACARS capacity for AOC applications the airlines will, from 2005, migrate their existing/and introduce new AOC applications over to the bit oriented VDL Mode 2 link in a point-to-point fashion.

Both the DCL and ATIS applications will migrate to the new VDL Mode 2 link and additional ATS applications (as defined in the operational context) of a time/safety critical nature will be introduced due to the increased capability of the VDL Mode 2 link.

Due to certain limitations in the VDL Mode 2 link (e.g. lack of priority support, non-deterministic transit delays) it is generally agreed that it will be replaced by an enhanced mode of operation, e.g. Mode 3, 4 etc. in the 2010 timeframe. However, there is currently no consensus as to which Mode will be selected to replace Mode 2. This replacement Mode is hereafter referred to as Mode “X”. Studies and simulations need to be conducted in order to forecast the required data link capacity for the European region and the extent to which the VDL Mode 2 link will be capable of satisfying this capacity and for how long. This also applies to the ATN scenario since it also assumes that VDL Mode 2 will be the primary air/ground data link.

A key issue that needs to be addressed in both the ATN and baseline scenarios will be the comparative avionics and ground system costs involved in transitioning from a VDL Mode 2 to a Mode X environment.

C.3.3.3 FANS 1/A

It is expected that a limited FANS 1/A based ATS service will be provided in the NAT region from 2000 onwards. In the EUR region it is expected that a FANS 1/A service will be provided in the Low Traffic Level Areas (LTLA) and Low Traffic Level Areas-Remote (LTLA-R) areas from 2000 onwards.

With the assumption that VDL Mode 2 will replace ACARS it is expected that the FANS 1/A applications (ADS, CPDLC) will migrate to operate over the VDL from 2005 onwards.

C.3.3.4 Mode S

Mode S is expected to be deployed for surveillance purposes and use of the “Mode S Specific” services to enable enhanced surveillance are expected from 2005 onwards. Mode S datalink (i.e. the Mode S subnetwork) is not expected to be deployed.

C.3.3.5 AMSS Data 3 Service

In the absence of an encompassing ATN infrastructure it is expected that use of the Data 3 service will be made in a similar way to that envisaged for the VDL Mode 2 service, i.e. "point-to-point" X.25. It is expected that such a service would be introduced from 2005 onwards.

Like VDL, the AMSS Data 3 service has been designed with the intent that it be integrated into the ATN infrastructure. Consequently, its use in a stand-alone fashion will result in the need for additional functionality that was assumed to have been provided by the ATN in the delivery of the end-to-end communications service.

Given that Mode S data link is assumed not to be implemented in the baseline and the requirement for a complementary back-up air/ground subnetwork it can be concluded that the AMSS will be required to provide a back-up complementary service to VDL Mode 2.

C.3.3.6 Gatelink

It is expected that AOC applications will drive the implementation of gatelink products on aircraft from 2000 onwards. Gatelink applications will be tied to the technology, consequently, any changes in the technology interfaces will require changes to the avionics and ground system applications. Once the operational concepts have been defined it is expected that ATS applications may also require the use of the gatelink technology.

C.3.4 Evolution of Ground/Ground Infrastructure

C.3.4.1 ATSOs

The baseline assumes that the future ATS communications infrastructure will, from 2000 onwards, evolve to encompass:

- an interconnected ATSO X.25 network to support inter-centre communications and possibly future ATS data communications requirements e.g. of the CRCO;
- a TCP/IP Network Service based on the integrated ATSO X.25 network;
- a dedicated network to support the European AIS Database (EAD);
- a dedicated network to support radar data distribution;
- a Messaging Service based on the X.400 standard utilising private or public network services over which AFTN/CIDIN applications will migrate;
- a network service dedicated to meet the data communications needs of the CFMU;
- a network service dedicated to meet the data communications needs of the CRCO;
- network management systems for each of the above types of disparate networks based on various industry standards (e.g. SNMP).

C.3.4.2 Aircraft Operators

The major aircraft operators are expected to continue to use the services of communications service providers (e.g. SITA, ARINC) for their wide area data communications requirements and/or continue use and deployment of various proprietary (e.g. IBM SNA) or standardised (X.25) networks.

Interconnections with the ATSO and APO related networks will need to be through either standardised or specialised ad-hoc gateways.

Aircraft operators are expected to make expanding use of the commercial Internet to support their business operations as its capabilities expand (e.g. security, coverage through global LEO satellite systems, increased performance).

C.3.4.3 Airport Operators

The major and large airport operators will continue to deploy airport standardised (e.g. Ethernet) or proprietary Local Area Networks to support their operations. Any airport requirements for wide area data communications are expected to be serviced through communications service providers (e.g. PTT, ARINC, SITA).

Interconnections with the ATSO and AO related networks will need to be through either standardised or specialised ad-hoc gateways.

C.4 Baseline Assessment

C.4.1 Transition

The baseline infrastructure assumed in the scenario is essentially a number of independent networks. The transition requirements defined in Annex B.2 therefore apply to each network type.

Issues related to the introduction of new air/ground technologies and their impact on existing airborne and ground systems need to be studied, e.g. introduction of LEO satellite based services. Similarly, as new ground/ground technology is introduced to replace networks services dedicated to supporting EAD or CFMU then the impact on existing system interfaces and applications needs to be studied since such systems and applications may be tied to the technology being replaced. [REQ1].

The baseline scenario may maximise the return on existing investments through the deployment of gateways, e.g. ACARS/VDL Mode 2 and AFTN/AMHS (as yet to be defined). The baseline does not assume the definition of standard application interfaces to facilitate the replacement of “legacy units” as new technology is introduced. This implies that application interfaces are subject to change with each introduction of new technology. The baseline scenario does not encourage the development of a common network infrastructure and therefore as new applications are introduced there is a potential of deploying and/or leasing additional network services rather than maximising cost-effectiveness through utilising existing infrastructure. [REQ2], [REQ19],[REQ24], [REQ25].

It is not clear how the air/ground capacity needed of the baseline scenario may be increased “at relatively short notice”. A VDL Mode 2 based system may be capacity constrained due to its inherent (CSMA based) limitation until it is replaced by the next Mode (i.e. Mode X). Whilst this is also true in the ATN scenario the additional required capacity could be provided transparently through either Mode S or AMSS with no impact on the applications [REQ33], [REQ34].

Each network type foreseen for deployment in the baseline is potentially scalable to the point that capacity constraints are reached. Beyond this point requires introduction of new and/or additional capacity, which may prove to be expensive in terms of impact on the end system applications. [REQ44].

Each network type of the baseline is expected to be deployed on an evolutionary incremental basis with each step expected to provide technical and/or economic benefits. [REQ46], [REQ47].

The baseline is expected to comprise a number of application specific networks in which the applications utilising the networks are directly interfaced to them. The applications are therefore subject to change with each evolutionary change in the network that has an impact on the network/application interface. This poses a significant transition problem since any migration to a new network technology (e.g. VDL Mode 2 to VDL Mode X) may potentially require all ground based and airborne data link applications to be modified and possibly re-certified.

C.4.2 Seamless Integration

The air/ground and ground/ground networks foreseen for deployment in the baseline will not be integrated into a seamless internet. For ground/ground services it is likely that each network will be specific to a limited number of applications. Exchange of information between network types will need to be via gateways that will need to be specified, developed and deployed. The provision of a “common information pool” to be available to air/ground and ground/ground applications, though theoretically possible, will not be efficient or optimal since, inter alia, gateways will be required to be deployed for interconnecting each network type. [REQ3], [REQ5]. Application-level gateways may also be needed in some instances.

Due to the separate non-integrated manner in which the air/ground data subnetworks are expected to be deployed in the baseline it has not been defined how an aircraft would switch from using one subnetwork to another in a manner that is transparent to the user.[REQ6], [REQ57].

The baseline assumes that the AMSS subnetwork will always be available as a back-up to the primary VDL Mode 2 subnetwork. [REQ7]

As indicated, the provision of a “common information pool”, though theoretically possible, may prove to require so much overhead in deploying ad-hoc gateways, address management etc. that it is not practical to deploy. The lack of such a common information pool may prevent the efficient implementation of future ATM enhancements such as collaborative decision making, 4-D trajectory negotiation.

Furthermore, as the various air/ground technologies are not integrated under a common “umbrella” mechanisms and/or procedures need to be developed which determine the manner and criteria by which aircraft switch from using one air/ground subnetwork to another.

C.4.3 Competitive Service Provision

For air/ground services the baseline offers limited possibility for competitive service provision. It is probable that avionics will be developed to be compatible with the services offered by a limited number of service providers. The nature of the solution adopted for migrating ACARS applications to the bit-oriented networks (i.e. VDL, AMSS) may additionally influence/limit the possibility of competitive services being offered.

In order to promote competition, institutional requirements may be imposed that require owner of the network infrastructure (e.g. SITA, ARINC) to make capacity available to other commercial service providers wishing to enter the market.

For ground/ground services it will be possible for users of the application specific networks (e.g. CFMU) to switch from one service provider to another. [REQ8].

Should the baseline comprise solutions that are based on proprietary solutions and/or products then, in order to promote competition, it may be necessary to introduce legislation whereby all such IPR is placed in the public domain.

C.4.4 Priority Management

For VDL air/ground services there are no priority mechanisms defined for operation above the subnetwork level. The VDL Mode 2 network itself does not support priority handling. This implies that situations may arise whereby short tactical high priority messages may be queued and delayed behind lengthy lower priority messages. The AMSS air/ground service does support a multi-level priority scheme derived from ITU regulations. There are no means defined to detect and recover from congestion at either the subnetwork level or above. [REQ9],[REQ72],[REQ74].

The lack of a priority mechanism in the primary subnetwork selected for air/ground data communications, i.e. VDL Mode 2, may prove to be a serious limitation in an ATS environment. It has the potential to result in low priority AOC messages being treated in preference to high priority ATS messages. The ATN overcomes this limitation through its priority scheme, which operates at one level above the subnetwork, i.e. the “internet” level. The lack of a congestion avoidance mechanism may prove to be an equally serious limitation in the ability of the network to maintain a service for at least high priority ATS data in periods of congestion.

C.4.5 Global Inter-operability

Given that the baseline assumes the ICAO defined VDL and AMSS subnetworks for air/ground services they will, by definition, support global inter-operability. This is in the sense that aircraft equipped with a single set of SARPs compliant equipment will be able to successfully inter-operate with ground equipment anywhere in the globe (assuming that all such equipment has adopted the same approach for its data link solution). For ground/ground services, however, global inter-operability with adjacent and remote States/Regions external to EUR will be achievable through the use of standard and/or ad-hoc gateways depending on the type of technology deployed. Furthermore the likelihood of ground based European aeronautical systems inter-operating successfully with systems outside the aeronautical domain will be subject to similar constraints, e.g. the need for gateways. [REQ10],[REQ31].

Should regions outside EUR adopt ATN for their data communications needs, then aircraft equipped to operate in their airspace will be unable to support data communications in European airspace since the baseline will comprise direct point to point VDL and AMSS services.

For ground /ground services, each network type in the baseline requiring connection to networks (whether ATN-based or not) outside EUR will require gateway functionality to be specified, validated and developed in the case where standard gateway products are not applicable. This will further extend the address mapping function that needs to be maintained.

C.4.6 Service Delivery

The baseline infrastructure will support the following types of communications services (in a non-integrated disjoint manner):

- ground/ground “end-to-end”;
- air/ground “end-to-end”;
- ground/air “end-to-end”:[REQ29]

The means to provide the following services in the baseline are yet to be determined:

- ground/ground broadcast;

- ground/ground multicast;
- ground/air broadcast;
- ground/air multicast;
- air/air broadcast;
- air/air multicast.[REQ29].

For air/ground and ground/ground services to be offered by the various baseline networks there is currently no defined means by which the service may be described in discrete service levels. [REQ12].

Due to the fact that the baseline is essentially a collection of disparate networks there will be no common network infrastructure and applications that may be shared by ATSOs, Airport Operators, Aircraft Operators and their aircraft to enable implementation of enhanced ATM concepts such as Collaborative Decision Making and 4-D trajectory negotiation. In order for the various aeronautical communities to exchange data they will need to agree on data exchange standards and applications and may additionally require the development of gateways to interconnect the networks of each user. [REQ16], [REQ28], [REQ43].

The AMSS and VDL networks will enable the exchange of data air/ground in all airspace types. [REQ48].

The ATSO interconnected network will be used to primarily support inter centre ATC communications (e.g. flight plan related data). It may potentially be able to satisfy the future ATS ground/ground data communications requirements, e.g. for CFMU and the CRCO.[REQ32], [REQ30].

The baseline infrastructure may be designed so that either aircrew or ATSOs are provided with the ability to terminate one or more Air Traffic Services provided by data link. The infrastructure can be designed so that the aircrew are provided with the ability to monitor and control ATM data link communications to and from the aircraft. [REQ62], [REQ63], [REQ67].

A “context management” application, similar or the same as that defined in the ATN SARPs, will be implemented in the baseline. This enables the controller to identify the data link applications supported by the aircraft following the aircraft’s log-on to the ground infrastructure. [REQ68] [REQ59].

The baseline assumes the replacement of the AFTN with a messaging system based on the CCITT X.400 standard. [REQ27].

The baseline infrastructure may be designed so that the controller may select multiple recipients for the same message. [REQ69].

C.4.7 QoS

The QoS for each ground/ground network in the baseline will be delivered through (1) appropriate dimensioning of the networks taking into account traffic forecasts and (2) systems/network management monitoring and control. Similarly, the QoS for the VDL and AMSS air/ground services will be maintained through independent and separate systems/network management and control. As soon as performance indicators suggest that the Mode 2 network is reaching its performance limits then the next VDL mode (Mode X) will need to be introduced. [REQ11], [REQ73].

In the event that the QoS supporting a particular ATS service degrades beyond the level

required the baseline infrastructure will be capable of notifying the controller and aircrew accordingly. [REQ64].

C.4.8 Policy Routing

For the networks deployed in the baseline there are no defined means by which users (e.g. ATSOs) may control, through policy, the types of traffic that transits through their networks. [REQ14]

Other than the foreseen interconnected ATSO network there can be no requirement for policy based routing since each network is specific to an application. In the interconnected ATSO network (X.25 or TCP/IP) there is no means defined to support policy routing and associated traffic typing. Such mechanisms (or similar) will need to be developed and validated in the event that ATSOs decide that they wish to be able to maximise utilisation of their resources through offering bandwidth to external users.

C.4.9 Gate to Gate Coverage

Due to the fact that there is no common network infrastructure envisaged for the baseline (it is a collection of disparate networks) there will be no efficient means to support services in support of the gate-to-gate concept which requires interchange of data between ATSOs, Airport Operators, Aircraft Operators, Aircraft, airport surface vehicles etc. However, with the assumption that networks of the various parties (ATSOs, AOs, APOs,) can be interconnected through standard and/or ad-hoc solutions it will be possible to enable gate-to-gate operations and services albeit in an inefficient manner and, possibly, with less performance. The use of such gateways results in the loss of the overall "end-to-end" communications service that may impact the achievable integrity of the service. [REQ15], [REQ36], [REQ37], [REQ43]

C.4.10 Geographic Scope

The baseline will be capable of providing a uniform service over the ECAC/EUR regions albeit in a non-efficient manner due to the multiple application specific networks, multiple management systems and ad-hoc gateway solutions expected to be deployed. [REQ11],[REQ17]

C.4.11 Cost/Effective Infrastructure

The baseline scenario envisages a number of disjoint networks evolving to support specific applications/application groups, e.g. networks for CFMU, CRCO, inter-centre co-ordination, EAD. Each such network will require its own set of dedicated resources to plan, operate, manage, bill and maintain the service provided. The baseline does not offer a single common infrastructure to the aeronautical community and an associated single point of billing for services. Existing dedicated point-to-point links are expected to be replaced by these appropriate network services referred to above. Though not precluded from a technical perspective the baseline does not foresee the operational networks also providing services for administrative purposes.[REQ18], [REQ21], [REQ23], [REQ26], [REQ35], [REQ39]

Where the baseline networks are based on international or de-facto industry standards the baseline may use commercial off the shelf products, e.g. in the case of the interconnected ATSO TCP/IP network. [REQ20]

Due to the various network types that are foreseen to exist in the baseline, and the expectation that applications will directly interface to these networks in most cases, it is not possible for a single application programming interface to be standardised so that application modules are portable across differing network types. [REQ42].

C.4.12 Security

There are no security provisions defined for implementation in the air/ground subnetworks envisioned for deployment in the baseline (i.e. VDL Mode 2, AMSS, ACARS). However, if it is concluded that a standard is required it is expected that the industry would define it. [REQ22], [REQ49], [REQ50], [REQ70]

The lack of air/ground data communications security may prove to be a serious limitation when considering utilisation of data link to support enhanced ATM concepts which are highly dependant on secure communications.

C.4.13 Directory & Addressing

Each air/ground and ground/ground network foreseen for deployment in the baseline will have its own unique addressing scheme and directory application. It will not be possible to implement a common Europe-wide addressing scheme that is applicable to all air and ground components of the aeronautical environment. [REQ4], [REQ38], [REQ52]

The lack of a common addressing scheme will result in (1) multiple address management and allocation systems being established for each network type supported in the baseline and (2) multiple address mapping function being established for each network type interconnected through a gateway. It may prevent (or at least complicate) concepts such as the "common information pool" being established and therefore impact future ATM initiatives which rely upon such information management concepts.

C.4.14 Infrastructure Management

Each air/ground and ground/ground network type foreseen for deployment in the baseline is likely to implement its own system/network management system. It will not be possible to monitor or manage the total baseline infrastructure as a single entity, i.e. it will not be possible to monitor the "end-to-end" performance between systems. Each system/network management system will have the capability to provide configuration and operational status information of each of the network components under its control. [REQ13], [REQ40], [REQ41], [REQ65], [REQ71].

C.4.15 Delivery Notification/Message Delivery

Each network type envisioned for deployment in the baseline will implement its own specific means of ensuring correct delivery of a message and notifying the originator in the case of non-delivery. However, in the case of networks concatenated with gateways (with the exception of the TCP/IP ATSO network) there will be no overall end-to-end communications service possible and the ability to correctly report to the originator on non-delivery of a message will be limited or non-existent. Furthermore there will be no means to monitor and ensure the overall end-to-end integrity between users communicating over networks concatenated with gateways. [REQ51], [REQ54]

The ATN CPDLC SARPs, which are expected to be implemented in the baseline, contain an optional feature, the "Logical Acknowledgement", (LACK), which provides an indication to the originator of a message that its message has been received and is suitable for display/processing by the recipient. [REQ61]

C.4.16 Air/Ground Data Link Selection & Initiation

The means by which users may manually select the required air/ground data link is to be defined. [REQ55]

C.4.17 Baseline Feasibility - Conclusion

From the preceding sections it can be concluded that foreseen baseline infrastructure has

some significant limitations in satisfying the foreseen operational and non-operational requirements for the future European data communications infrastructure as presented in Chapter 2 and Annex B.

C.5 Conclusion

From the preceding sections it may be concluded that an ATN based infrastructure will be capable of satisfying the requirements of the future European ATS data communications infrastructure (as presented in Chapter 2 and Annex B) and may therefore be considered as both technically and operationally feasible.

The expected baseline infrastructure is considered to be deficient in a number of the key requirement areas to varying degrees. The significant shortcomings have been identified and, where applicable, an indication of the solutions that would be necessary in order to resolve the shortcoming. Consequently, it is concluded that the baseline is not a feasible option for satisfying the requirements of the future European ATS data communications infrastructure as defined in Annex B.