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ACCESS

ATN Compliant Communications

European Strategy Study

Deployment scenarios for air/ground subnetworks

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0.1 [VDL/2 part]	07/08/1998	Initial Draft of the VDL/2 Part “Deployment Scenarios for VDL Mode 2” (filename S038D0-1.DOC)
0.1 [AMSS part]	29/06/1998	Initial Draft of the AMSS Part “Deployment Scenarios for AMSS” (filename N090D0-1.DOC)
0.2 [AMSS part]	20/08/1998	Update of the Initial AMSS Part including deployment options (filename N090D0-2.DOC)
1.0	02/11/1998	Merging of the two previous WP220A documents (VDL Mode 2 and AMSS). Updates with STNA and DFS comments about VDL Mode 2 (filename S038D1-0.DOC).

EXECUTIVE SUMMARY

The purpose of the document is to propose an air/ground subnetworks' architecture for the ACCESS area. This a/g subnetworks' architecture is one part of the future ATN network architecture tackled by ACCESS. But as the deployment scenarios for the ATN a/g subnetworks in Europe (namely, VDL Mode 2 and AMSS) are not known today, this report of the ACCESS work package 220A is dedicated to the identification and the description of the most probable deployment scenarios for VDL Mode 2 and AMSS in terms of location of ground stations and connectivity of these ground stations to ATN routers.

The document successively presents deployment scenarios, respectively for VDL Mode 2 and AMSS.

Two main strategies are identified for the provision of VDL Mode 2 subnetworks in Europe:

- the first one is driven by CSPs, which will need to expand their a/g data link systems in order to meet airlines' requirements, mainly for AOC traffic (ATSC would be an additional source of revenues in that case): that strategy would be essentially driven by economic factors,
- the second one is driven by ATSOs, which are supposed in that case to have the will to keep control of the VDL Mode 2 deployment and operation for ATSC traffic. This strategy would be essentially justified by long term concerns, e.g. related to safety or institutional issues.

A deployment scenario for each strategy is presented, after the specific requirements and constraints of the VDL Mode 2 service have been outlined (e.g., scarcely available VHF frequencies). However, in the light of the current trends for the VDL Mode 2 deployment, the first strategy appears to be more realistic. This will probably lead competing CSPs (SITA and ARINC) to provide a similar coverage of the European core area by 2002, initially for AOC ACARS traffic only, while a later parallel implementation based on the second strategy will allow the support of more and more ATSC traffic.

In conclusion for VDL Mode 2, the document outlines the importance of AOC and institutional issues for the future deployment of VDL Mode 2 subnetworks.

Concerning AMSS subnetworks, it should be recognised that AMSS is unlikely to be the preferred air/ground subnetwork in the core European area since other subnetworks (e.g. VDL, Mode S) will be supported in the region and are likely to provide a more cost effective capability. The use of AMSS may be restricted to fringe areas where existing infrastructure is limited such as the Mediterranean or Eastern Europe. It may also provide a backup capability to support the preferred air/ground subnetworks under failure conditions.

However, following the presentation of the current landscape of satellite service providers (based on the Inmarsat system), the document describes three possible interconnection scenarios for AMSS with the corresponding advantages and disadvantages of each scenario. No selection of a preferred scenario can be made at this stage of the study.

In conclusion for AMSS, the document highlights the possibilities that may emerge in a near future with new competitors using LEO/MEO satellite systems, designed to be global systems not dedicated to ATS services (which would then require the definition of specific service level agreements to meet the strict quality of service requirements of ATS providers).

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1. Introduction

1.1 Purpose of the Document

The main objective of ACCESS Part 1 is to propose a complete ATN network architecture in the ACCESS geographical area. The air/ground subnetworks architecture is an input element to this future ATN architecture, but its design is a specific issue which is not itself the object of ACCESS Part 1 (ideally it would have been provided as an input to the work in ACCESS). Unfortunately the deployment scenarios of the ATN air/ground subnetworks in Europe (e.g. namely VDL-2 and AMSS) are not known today. Consequently, in order to progress towards the proper completion of the main ACCESS Part 1 objective, the ACCESS work package 220A was created and dedicated to the identification and the description of the most probable deployment scenarios for VDL Mode 2 and AMSS in terms of locations of ground stations and connectivity of these ground stations to ATN routers.

Initially the WP220A was divided into two separate parts and consequently produced two separate draft reports:

1. The first one provides a technical description of the possible scenarios for the deployment of a VDL Mode 2 subnetwork in the European region and considers the possible differences of strategy of the organisations that could potentially be involved in implementation of such an infrastructure (ARINC, SITA, and the ATSOs).
2. The second one outlines a potential deployment scenario for the use of AMSS to support the implementation of the Aeronautical Telecommunication Network (ATN) in Europe, although it is likely that AMSS will not be the preferred air/ground subnetwork in the core European area since other subnetworks (e.g. VDL, Mode S) will be supported in the region and are likely to provide a more cost effective capability.

This document is the result of the merging of the two previous parts that were respectively issued by STNA (S.Tamalet) and NATS (J.Coulson and B.Cardwell) and updated from DFS comments (T.Belitz) about the VDL Mode 2 scenarios

1.2 References

Note: the content of this document for VDL Mode 2 scenarios has been derived for the most part from [1] and [2]. Many thanks to Michel Delarche, Phil Platt and Tony Whyman for their indirect contribution to the present report.

ACCESS Reference	Title
[1]	Study of VDL-Mode 2 Deployment in France - Phil Platt, Michel Delarche (Sofréavia) - Version 1.1 - 26 November 1997
[2]	Eurocontrol DED6/ATNCT/ProATN_Sup/DCI/AW_22 - Proposed ACARS Replacement Solutions - Issue 1.2 - 24/03/98
[3]	Draft ICAO Manual of ATS Data Link Applications' -version 0.4, 20/9/96
[4]	SCALA - CENA/STNA/SCTA - Version 1.4 - July 1996
[5]	EUROCAE ED 78 - June 1997
[6]	AIRCOM Status Report - SITA - June 1998 Issue

2. Deployment Scenarios for VDL Mode 2

2.1 Background

2.1.1 ACARS Limitations

The current implementation of VHF data link services is based on the Aircraft Communication Addressing and Reporting System (ACARS). In Europe, this system is operated by the Société Internationale de Télécommunications Aéronautiques (SITA)) and more recently also by ARINC (Aeronautical Radio Inc.), whose shareholders are the main airlines who use the system. This system has been in use since the early 70's and was designed to support airline communications for operational control and regularity of flight communications. The system has proved successful as witnessed by its widespread implementation. However its success has caused the system to reach the limit of its capacity and there is now very little scope for new uses of ACARS.

The ACARS network was designed over twenty years ago and therefore uses techniques and systems that are inefficient by today's standards. These are characterised by :

- a low-throughput low-integrity modulation designed for outdated analogue radios (the throughput is 2400 bps, while today using state-of-the-art techniques over a 25 kHz radio channel the throughput can be increased by at least an order of magnitude) ;
- character-oriented encoding (today state-of-the-art is to use bit-oriented frames);
- centralised message switches are used (today state-of-the-art is to use an Internet-like meshed network routing) ;
- no end-to-end transport service (today state-of-the-art is to have a reliable transport service based on either a TCP/IP or ISO protocol).

Among the weak points of the low speed ACARS system, the most prominent, and the most constraining for data link applications, especially for new more time critical ones, is the low nominal throughput (2400 bps) of the air-ground link. Today, even the modest Quality of Service (QoS) requirements of AOC applications are difficult to meet due to the growth of traffic on ACARS. Whatever has already been done, and is being done, to improve the efficiency of the ACARS network through various technical changes (for example, optimisation of MTN processing of message queues, upgrade of ground links, new encoding and error-correcting protocols, etc.), the air-ground data rate remains a major limitation. Also the current shortage of VHF frequencies makes it unlikely that more channels could be assigned to the current ACARS in Continental Europe.

Therefore, for the sake of both AOC and ATSC, there is a need to replace the current low speed modulation by a more efficient one.

In Europe, this need is coincident with the need to reduce radiotelephony (RTF) channel spacing to 8.33 kHz channels to enable more channels to be found. It is planned that the introduction of the reduced channel spacing will take place for channels supporting Upper Airspace Air Traffic Services around 1999 to 2000. As this will necessitate airlines equipping their fleets with new digital radios, there is an opportunity to build into these radios a VDL Mode 2 capability as well. This concept has been accepted by the airlines and the AEEC standard 750 describes a VHF Digital Radio (VDR) capable of providing a data link using the D8PSK modulation of VDL Mode 2, providing a nominal throughput of 31,500 bps on a VDL-dedicated 25 kHz channel and having an 8.33kHZ channel voice capability too.

Despite the apparently fortunate timing which seems to ease the problem of having a high proportion of VDL Mode 2-equipped aircraft due to the need to replace existing radios with those compatible with 8.33 kHz voice channels, the airlines will require a business case to order the VDL capability with the new radios. A strong business case will arise from a combination of airline communication requirements and beneficial ATS data link services; this combination of benefits to Airlines (improved ATS capacity owing to 8.33 kHz, and improved AOC and ATSC services owing to a more spectrum efficient data link) strengthens the case for an early migration to new VDRs by the airlines.

2.1.2 Improvement Strategies and Scenarios

Based on the above it is clear that a replacement for ACARS is highly desirable. The introduction of VDL Mode 2 to improve the air-ground link at the physical and logical link level will overcome many of the identified problems but will require investment. As well as airline investment, there is also the need for investment in ground transmitter and receiver equipment compatible with VDL Mode 2 operation. The investment in ground equipment can be made either by the ATS service provider (there may be opportunities for co-sitting of VDL Mode 2 equipment and RTF equipment operating on 8.33kHz channel spacing) (ATSO driven VDL Mode 2 deployment strategy) or by airline communication service providers in response to airline requirements (CSP driven VDL Mode 2 deployment strategy).

Both strategies raise a number of questions, and they provide a useful and suitably contrasted framework for consideration of the options for deploying VDL Mode 2. In the remainder of this document, the issues and problems of deploying VDL Mode 2 in Europe are explored using these two strategies. In reality there could be combination of the strategies, for example, the deployment scenario for the Communication Service Provider strategy can include or not the early provision of an ATN interface, the deployment scenario for the ATSO-driven interface can be European or national, and it can be ATSC-only or include some AOC.

Other possibilities include a scenario based on agreement with a CSP for the support of traffic for airport AOC and ATSC services (e.g. using the CSP network on airports) and deploying an ATSO VDL system for en route ATSC and AOC services.

One of the main criteria to be considered in a complete analysis and comparison of the CSP and ATSO driven strategies for the deployment of the VDL Mode 2 relates to economic issues. Implementation of a VDL Mode 2 subnetwork will incur a considerable capital expenditure, and it will also have significant running costs. The revenues (providing some return on investment) that could be gained by an ATSO in the transport of AOC traffic over its proprietary VDL subnetwork would need to be considered; the delta of the costs and of the benefits would have to be compared to the charges that would be made by a CSP to handle ATSC transactions over the CSP network. The effort necessary to make such an analysis is however not available in the scope of this Work Package. This study will therefore be limited to the identification of potential differences, where they occur, related to operational, technical, or institutional issues in the deployment of VDL Mode 2.

2.2 ACARS Transition and VDL Mode 2 Deployment

2.2.1 Introduction

In an ATN implementation perspective, the VDL Mode 2 is generally perceived as one ATN subnetwork. On the other hand, the airlines consider primarily the VDL Mode 2 as the successor to ACARS.

ACARS is very popular today. The rapid growth in demand for ACARS services exceeds the 5-7% annual growth rate in Air Traffic Movements, because:

- the increase in the number of frequency of flights forces airlines to increase the level of automation in their ground system and requires a direct datalink to aircraft to maximise efficiency;
- the increase in automation of aircraft systems (e.g. a Boeing 777 generates four times as much traffic than older aircraft);

and this can only get worse as increased use of ATC automation is introduced.

The world's major airlines have integrated ACARS and the associated on-board applications into their operating systems and procedures. For the airlines, ACARS is an essential element in maintaining operating capability. ACARS will continue to be used for some years as many airlines have invested a lot of money in developing AOC applications and are reluctant to move too quickly to more modern technologies which add no additional benefits.

Faced with such facts, and to the VHF ACARS bottleneck, it is clear that a strategy is needed to make available improved data link capacity for the current ACARS applications.

Different strategies may be adopted by the airlines for upgrading the current VHF ACARS service to VDL Mode 2 and the strategy adopted could be a key determinant on the strategy for the VDL Mode 2 subnetwork deployment.

This section discusses the different ACARS migration strategies and their possible influence on the VDL Mode 2 deployment.

2.2.2 ACARS Upgrade Requirements

An increase in the capacity provided by VHF ACARS is essential and VDL Mode 2 is the only available air/ground data link that can meet this requirement. The principal requirement is therefore that the VHF ACARS service is upgraded to use VDL Mode 2. In addition:

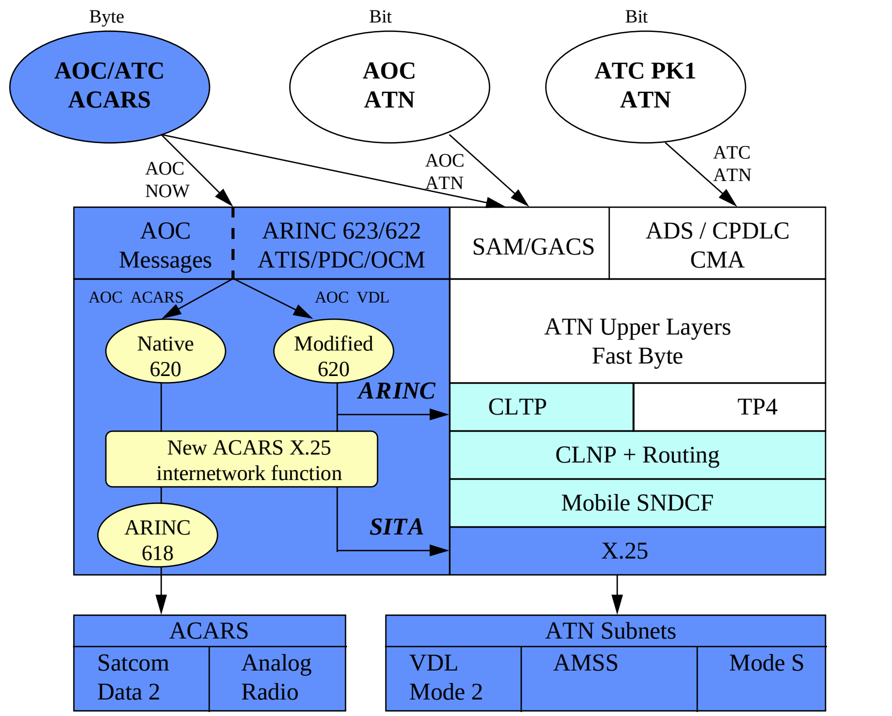
1. The ACARS service must be upgraded without affecting the end user service. There must be no change required to the ground interface to airlines and any changes to take advantage of improvements other than increased capacity should be discretionary for each airline. The airborne interface to external systems must also be unchanged.
2. During the transition phase, while VDL Mode 2 is introduced, both VHF ACARS and VDL Mode 2 will need to be supported by upgraded aircraft with a seamless transition from one mode of use to the other. Network operators will indeed likely first provide VDL coverage in areas already experiencing high datalink traffic loads such as the European Core area. This means that aircraft have to be able to switch from VDL X.25 connections to AEEC 618 connections when the aircraft leaves the coverage of VDL ground stations.
3. ACARS already includes a satellite based data link and HF services are being introduced. The ACARS upgrade must accommodate networks other than VDL Mode 2 with again a seamless transition from one network to the other.
4. The re-equipage timescale for the introduction of VDL Mode 2 into aircraft overlaps with the necessary introduction of the ATN. Transition to the ATN should therefore be accommodated within ACARS upgrade strategy

2.2.3 ACARS Migration Strategies

2.2.3.1 The Different Approaches

Two alternative approaches to the upgrade of ACARS to use VDL Mode 2 technology have been tabled - one essentially from SITA and the other from ARINC . The SITA proposal is a minimalist approach aimed solely at replacing VHF ACARS with VDL Mode 2. On the other hand, the ARINC proposal additionally includes the use of ATN protocols and procedures. The detailed description and analysis of the 2 proposals is provided in [2]. The summary presented below has mainly been derived from this document.

In order to illustrate the technical differences between the two proposals, the figure below attempts to capture the two proposals as protocol stacks, and to contrast them with the existing ACARS protocol stack and the ATN protocol stack.



VHF ACARS is a character mode communications protocol whilst the ATN provides for binary mode communications, as does VDL Mode 2. All the proposed solutions involve some sort of "cross-over" between these stacks, so that character mode ACARS can make use of the binary VDL Mode 2. As shown in the figure, there are 2 suggested possibilities for this "cross-over":

- SITA: at the VDL Mode 2 Network Access Service (X.25 compliant service)
- ARINC: at the Connection Less Transport Service Level

In the medium and long term co-existence between the Byte oriented applications and the bit oriented ATN network and subnetworks may be provided by SAM/GACS, thus avoiding the need for such cross-overs. However, the cross over is the essential feature of any transition solution.

2.2.3.2 SITA Proposal

2.2.3.2.1 General

The proposed approach is understood to be essentially minimalist in intention, the aim being to upgrade ACARS to VDL with least disruption to the end-user service and the existing implementation. As a consequence, a relatively painless transition is also hoped for.

The basic characteristics of the SITA proposal are:

- Transmission of AOC/ATC ACARS messages over VDL Mode 2 via Enhanced ARINC 620 (and ACARS X.25 Internetworking Function) directly over X.25 with no ATN Internet functionality. This will be achieved by an ACARS/X25 convergence function.
- Continued use of ARINC 620 format for compatibility with current ACARS implementation,
- Enhancement to ARINC 620 to:
    - provide a non-ATN internetworking functionality on the ground (DSP) and in the aircraft in addition to current message handling functionality,
    - support current byte-oriented application data using VDL bit oriented transmissions rather than ACARS,

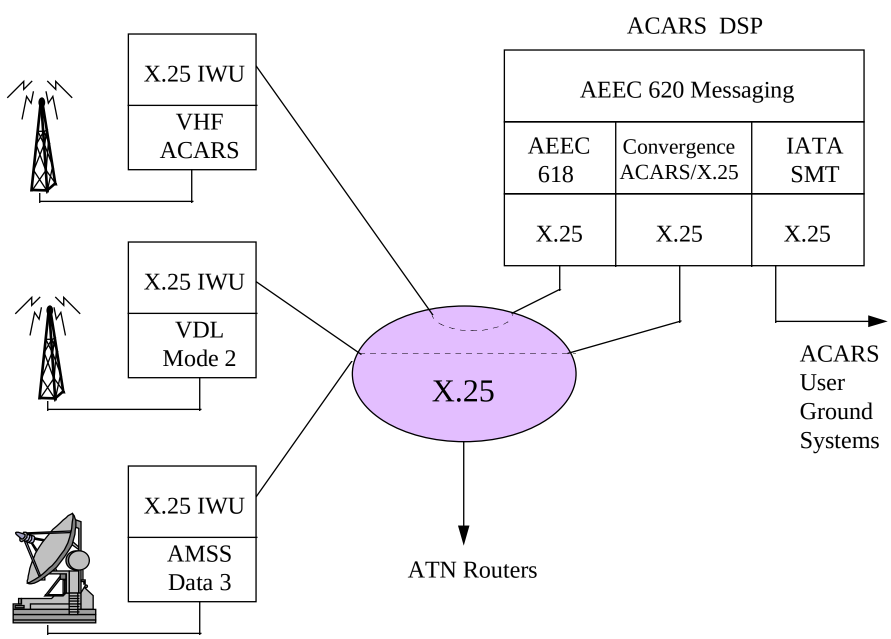
2.2.3.2.2 Associated Ground Architecture

Figure 2 illustrates an example of how the ground architecture could develop with the SITA proposal.

This figure shows how the ground stations will support the use by aircraft of the X.25 subnetwork capability to establish connections to multiple ground systems, including an ACARS DSP and potentially airline ACARS ground systems and ATN Routers.

This architecture requires the service providers to modify their DSP implementation to include direct support of VDL Mode 2 and AMSS Data 3.

A possible alternative, avoiding the modification of the DSP, is the use of some sort of Gateway between the ARINC 620/618 style of operating and the VDL Mode 2/AMSS Data 3 style, and which would appear to the DSP as one or more "Plain Old ACARS" VHF ground station.



2.2.3.3 ARINC Proposal

2.2.3.3.1 General

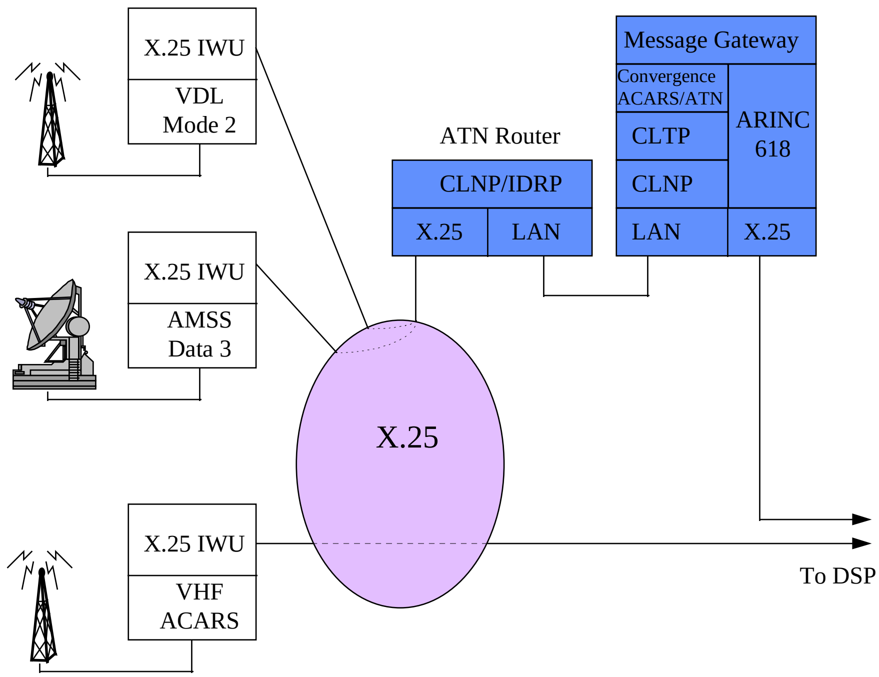
The ARINC proposal can be viewed as building upon the SITA proposal in order to include a transition path to CNS/ATM. The VDL Mode stack is enhanced to include the CLNP, the CLTP and the mobile SNDCF for use with both VDL Mode 2 and AMSS data 3.

Transmission of AOC/ATC ACARS messages over VDL Mode 2 is then performed using the ATN lower layers protocols via the implementation of an ACARS/ATN convergence function.

As for the SITA proposal, the ARINC proposal allows the continued use of ARINC 620 format for compatibility with current ACARS applications.

2.2.3.3.2 Associated Ground Architecture

The figure below illustrates the proposed ground architecture associated with the ARINC proposal.



The principal change to the ground architecture is the inclusion of an ATN Router. The expectation is that this is physically co-located with a message Gateway (although that is not essential).

2.2.3.4 Relation to Recent AEEC Activity

There has been considerable discussion on the pros and cons of both approaches. SITA argues that the installation of ATN Internet Software in airborne equipment may only be justified in conjunction with FANS applications having a direct ATN interface and considers that requiring the use of ATN could delay the implementation of the VDL Mode 2. On the other hand, the ARINC solution proponents consider that the SITA proposal gives no transition path to the CNS/ATM and the ATN except a replace all, nor does it readily support direct connect to aircraft through VDL Mode 2 by ATC providers. A clear risk of the SITA approach (even if it implies a CMU/ATSU upgrade on board) is therefore that the introduction of CNS/ATM would be compromised with longer timescales being necessary, or airlines would be faced with early replacement of the VDL Mode 2 upgrade with the consequential financial impact this implies.

Within the AEEC community it has been recognised that both solutions are possible and that both should be further investigated and further developed technically. Detailed work on ARINC specifications is underway for both solutions.

It has become evident to the airlines that it was not possible to choose one approach over the other on its technical merits. Ultimately, consensus was reached within the AEEC community that data link service providers and avionics manufacturers support both alternatives and let the market make the decision. The CSPs have responded that they would support the requests of their VHF data link customers. The airlines must therefore each decide which approach fits their requirements the best and work with their avionics vendor to implement that approach in their avionics.

2.2.4 Impact of the ACARS Migration Strategies on VDL Mode 2 Deployment

It is difficult to assess the impact that the choice by the airlines of one of the two approaches could have on the deployment of the VDL Mode 2. The choice will more certainly impact the deployment of the ATN ground infrastructure: the selection by the airlines of the SITA solution would indeed certainly block for a given time the deployment of the ATN, whereas the adoption of the ARINC pre-ATN approach would enable extensive in-service testing of the concept to be undertaken before CNS/ATM services need to be introduced, and would then expedite their introduction.

As concerns the impact of the selected approach on the VDL Mode 2 deployment, the following could be considered:

1. The only purpose of the SITA approach is to migrate as quickly as possible the current AOC applications from ACARS to VDL Mode 2, so as to overcome the limit of capacity that is experienced in the European areas of high air traffic density where there is a shortage of available VHF channels. The only requirements for the introduction of the VDL Mode 2 would then be where the AOC is limited by the current ACARS, for example in the most congested areas such as major airports and high traffic density areas. In other areas, where the current ACARS VHF capacity is sufficient, there would not be strong requirement in the short and medium term to deploy a VDL Mode 2 ground infrastructure. In those areas, the CSPs could delay the implementation of VDL Mode 2 ground stations so that to minimise the implementation costs and maximise the return on investment on the current VHF ground stations.
2. If the SITA approach was selected by the airlines, there would be little opportunity for the ATSOs to position themselves as VDL Mode 2 Subnetwork Service Providers. This is because the only return on investment that could be expected on the deployment of a VDL Mode 2 subnetwork would be the transport of the legacy ACARS traffic, and it is unlikely that ATSOs could participate (if willing) in the ACARS business.
3. With the ARINC approach and the availability of an ATN stack on board, the airlines could be encouraged to develop their new applications as native ATN applications. This would introduce an earlier requirement from the airlines for a global VDL Mode 2 coverage in Europe similar to the current VHF ACARS coverage. This could consequently accelerate the deployment of the VDL Mode 2.
4. Similarly, with the availability of an ATN stack on board, earlier initiatives of the ATSOs to provide initial ATS data link services would be encouraged. This could lead to the requirement to deploy the VDL Mode 2 in the areas where these ATS services are implemented.

2.3 VDL Mode 2 Implementation Requirements and Constraints

2.3.1 Introduction

This chapter identifies and discusses the potential technical requirements and constraints, to be considered in the analysis of VDL Mode 2 deployment scenarios.

2.3.2 Throughput and Quality of Service Requirements

2.3.2.1 Introduction

The difference between AOC and ATSC communications on throughput and QoS requirements may influence the VDL Mode subnetwork deployment. This is discussed in the following subsections.

2.3.2.2 QoS Requirements

2.3.2.2.1 QoS Requirement for AOC Communications

The salient characteristics of current AOC applications are:

- The requirements in terms of availability and reliability are moderate, since none of these applications is critical for the safety of the flight; yet, to be operationally efficient, the availability must be good, and temporary loss of the communication service must be short. All the more so since the highly centralised architecture of the network makes it likely that a problem somewhere will quickly result in the build-up of a huge pile of pending messages in the central switch and/or in regional concentrators, thus reducing the performance everywhere. So the maximum service outage is expected not to exceed 1 minute per day, and the unavailability rate is expected to be smaller than 10^{-3}, yielding a MTBF in the order of 1000 minutes (i.e. roughly a 1 minute failure per day).
- The Residual Bit Error Rate should not exceed 10^{-6}, leading to an undetected message error rate better than 10^{-3}
- The transit delay in not a major issue: for all AOC applications, a 95% transit delay of 60 s (with an average delay between 10 and 30 seconds) is acceptable.

2.3.2.2.2 QoS Requirement for ATSC Communications

For ATSC, the most critical quality figures derived from ADSP documents [3] for ADS-C and CPDLC services are :

- maximum service outage: 30 seconds
- availability: 99.996 %

The continuity of service is set by AMCP at the same value as the availability, except that no observation time range is currently available. If the observation time range is the mean duration of an ECAC flight, this means that the probability of a service outage for an aircraft should not exceed 4.10^{-5} over an 80 minutes observation period.

The integrity is defined as the Residual Bit Error Rate per message (10^{-7})

As far as the transit delay is concerned, the following 4 operational 95% transfer time classes have been identified from the compiled ODIAC information:

- class C1: 5-8 seconds,
- class C2: 10 seconds,
- class C3: 15 seconds,
- class C4: 60 seconds or more if necessary (all AOC transactions belong to this class)

These 4 categories correspond respectively to the following ATN ATSC transit delay classes:

- class A (7 seconds of ATN delay)

- class B (9 seconds of ATN delay)
- class C (13 seconds of ATN delay),
- class F (74 seconds of ATN delay).

It must be noted that the transit delay experienced over a VDL Mode 2 channel is a function of the amount of channel capacity being used: the more channel capacity is used, longer are the transit delays. The subnetwork may therefore have to operate below its maximum capacity in order to fulfil the ATSC transit delay requirements and the choice of final channel capacity must be a trade-off between the throughput and delay requirements

For instance, from the Eurocontrol COM ET2.ST15 Phase 1 Report, supplemented by information from Thomson-CNI, it has been estimated [1] that, for an en-route environment with several hundreds aircrafts, then:

- to accommodate C1 transactions, the traffic input on the channel should probably not exceed 6 kbps,
- to accommodate C2 transactions, the traffic input on the channel should probably not exceed 7.5 kbps,
- to accommodate C3 transactions, the traffic input on the channel should probably not exceed 9 kbps,
- to accommodate C4 transactions, the traffic input on the channel should probably not exceed 12 kbps.

2.3.2.3 Throughput Requirements

The throughput requirements for AOC and ATSC communications will be one of the key determinants of the VDL Mode 2 deployment. VDL Mode 2 has indeed, as ACARS/VHF, a limited capacity, and increased VDL Mode 2 capacity can only be accommodated by the use of additional frequencies, implying the deployment of additional stations (the use of multiple VHF channels to accommodate the throughput requirement is discussed in section 2.3.3)

The assessment of the VDL Mode 2 throughput requirements for AOC and ATSC communication in the different parts of the ACCESS region is however beyond the scope of this study.

In this study, it will simply be considered that the VDL channel capacity is 13 to 15 times higher than the VHF ACARS, and therefore that the use of one single channel will be sufficient at the beginning to accommodate the throughput and transit delay requirements.

This assumption is enforced by the following additional considerations:

- in Europe, the percentage of aircraft equipped with a VDL Mode 2 radio could increase rapidly, due to the migration towards the 8.33 kHz channel spacing for voice, to be started in 1999. However, up to half aircraft could be retrofitted with a lower cost analogue replacement of their present radios instead of installing a VDL-compatible system, and would remain on the ACARS in parallel.
- In airports, gate traffic could be transferred to the proposed high-speed Gatelink system being considered by the airlines for use at major airports where there is a large data exchange requirements. Although this will probably not be the case in the short term.
- ATSC applications would enter into operation rather slowly, due to the lengthy delays entailed by the modification of ATS procedures.
- The first operational ATSC services will not be the ones with requirements on very short transit delays (Only C3 and C4 transit classes should be required at the beginning).

It is assumed that requirements to use several VDL frequencies will appear progressively after the initial VDL Mode 2 deployment in the core area. Scenarios for the utilization of new VDL channels, for a given VDL Mode subnetwork service provider (CSPs or ATSO) are discussed in Chapters 2.4 and 2.5.

2.3.3 Use of Multiple VHF Channels

When a given service volume is too large for throughput and transit delay requirements to be met with a single frequency, two different strategies can be applied:

- **spatial splitting:** different stations covering a given Service Volume operate on different frequencies, but at a given point in airspace, only one frequency is used. Spatial splitting is typically applied by associating one of the frequencies operating in the volume, for use within a well specified altitude range (e.g. frequency F1 is used on the ground, frequency F2 is used below 15000 feet, and frequency F3 is used above 15000 feet). Another possibility is to use different frequencies in different groups airspace regions (e.g. frequency F3 in the core area, frequency F4 in the non core area)
- **functional splitting:** the stations are duplicated so as to operate on several frequencies, and different applications are mapped onto different frequencies (e.g. AOC traffic uses frequency F1, ATSC traffic uses frequency F2). This strategy requires to equip the aircraft with several VDRs.

It may be technically and economically difficult to operate several VDRs simultaneously on an aircraft, and therefore only the spatial splitting strategy is considered in this study. It must be noted that the technical and economical difficulties of the functional splitting restrain the scope of the investigations in the analysis of different VDL Mode 2 deployment scenarios: if it was possible to map different classes of traffic on different frequencies, it would have been possible to investigate deployment scenarios where different types of data link traffic are under the responsibility of different VDL Mode 2 subnetwork operators (e.g. AOC traffic for the CSPs, ATSC traffic for ATSO); the competition between the different operators would then have been focused on the attribution of responsibilities for different classes of traffic.

With the spatial splitting strategy, the competition takes place on the coverage of the different service volumes, and, when different subnetwork service providers (CSPs ad ATSOs) are allowed to operate in the same service volume, on the number of subscribing airlines. In the framework of the options for deploying VDL Mode 2, the spatial splitting strategy introduces possibilities of co-operation between the different subnetwork operators, for instance the scenario based on agreement of an ATSO with a CSP for the support of ATSC and AOC traffic at airports, while the ATSO is responsible for the en-route ATSC and AOC traffic. Without co-operation, and the sharing of responsibility for the coverage of the different service volumes, there will be competition between the different subnetwork operators. The airlines will be free to choose the cheaper service provider. In the increased competition for communication service provision between ARINC and SITA in Europe, it will then be more difficult to guarantee that an ATSO owned and operated VDL system could compete with SITA and ARINC in carrying AOC communications. Therefore it will be difficult to guarantee that many airlines will subscribe to the ATSO VDL Mode 2 subnetwork service and consequently contribute to a return on investment.

2.3.4 Service Volume Coverage Requirements

2.3.4.1 General

As introduced in the previous section, one of the factors influencing the VDL Mode deployment will be the requirements of the different actors (airlines, CSPs, ATSOs) on the coverage of the various airspace service volumes. There might be different relative priorities on different categories of service volumes depending on the relative cost-advantages for AOC and ATSC activities.

The categories of service volumes to be considered with respect to coverage requirements are assumed to be very similar in the ATSC and AOC cases: it is assumed that in the 2000-2010 timeframe, the user population of both AOC and ATSC data link services users will consist mainly of IFR-capable high-end aircraft for Commercial Air Transport and Business Aviation; consequently, the priorities for the VDL Mode 2 subnetwork coverage are: medium and large size airports and their TMA, on one hand, and the upper airspace in between, on the other hand.

Hence, according to the various data link services envisaged, three categories of service volume can be identified:

- upper airspace: continuous en route service volume from FL 200 upwards,

- lower airspace: medium and large TMA and airport service volume below FL 200,
- large airport: surface service volume

Priorities for implementation are very slightly different for ATSC and AOC.

For ATSC, the main priority is to provide a data link service in high traffic density areas (Core Area for en route, Major Airport TMA) so as to try to improve the ATS capacity where there is a salient need.

For AOC, the main priority is to have a better data link in those areas where the ACARS capacity limitations are most felt, and particularly on those airports where companies already operating the ACARS at the surface of the airport conduct their operation under tight scheduling constraints (hubbing, shuttle service) so as to improve the flexibility and responsiveness of their fleet management.

Since the high traffic density areas correspond to the areas where ACARS capacity shortage is experienced, it can be concluded that there are very strong similarities in the requirements from both AOC and ATSC viewpoints.

More detailed assumption on the likely initial coverage requirements in Europe are listed in the three subsections below

2.3.4.2 En Route Service Volume Requirements

The highest priority for en-route service volume coverage should be to provide continuous coverage over the ECAC Core Area, since it is the region where the current ACARS system is the most likely to be saturated soon (according to the current 20% annual growth ACARS growth rate (1998 issue SITA AIRCOM Commercial Brochure), the ACARS-dedicated frequencies will be saturated as early as 2000) and since it is the European High Traffic density area.

By 2003 at the latest, the following UACCs should therefore be covered:

Country	UACC
United Kingdom	London Manchester
Belgium	Brussels
France	Reims Paris Aix
Germany	Dusseldorf Frankfurt Karlsruhe Munich
Switzerland	Geneva Zurich
Netherlands	Amsterdam
Eurocontrol	Maastricht
Austria	Vienna
Italy	Milan

The requirements in term of en-route coverage can also be derived from the current alternate en-route VHF infrastructure that SITA has deployed so that to circumvent the ACARS shortage experienced with the SITA base VHF infrastructure.

This alternate infrastructure [6] covers a little more than the core area and consists of the 28 VHF RGS identified in the table below:

Country	current locations of SITA alternate en-route VHF RGS in Europe
United Kingdom	London Heathrow Glasgow Manchester
France	Paris Orly Paris CDG Brest Bordeaux Toulouse Nice Lyon
Germany	Dusseldorf Frankfurt Hamburg Munich Berlin Stuggart Cologne
Switzerland	Zurich Geneva
Netherlands	Amsterdam
Belgium	Brussels
Spain	Madrid Barcelona
Ireland	Shannon
Norway	Oslo
Sweden	Stockholm
Denmark	Copenhagen
Austria	Vienna

A suitable initial VDL Mode 2 VGS (VDL Ground Station) deployment can be deduced from this list by selecting the locations where a VHF RGS is currently covering a part of the core area airspace:

Country	Suitable Locations for an initial VDL Mode 2 coverage of the en-route service volume
United Kingdom	London Heathrow Manchester
France	Paris Orly Paris CDG Nice Lyon
Germany	Dusseldorf Frankfurt Hamburg Munich Stuggart Cologne
Switzerland	Zurich Geneva
Belgium	Brussels
Netherlands	Amsterdam
Austria	Vienna

2.3.4.3 Combined “TMA and Airport” Service Volume Requirements

It is estimated [4] that 60 % of the AOC data are exchanged between the aircraft and the airline operation officers on the ground, when the aircraft is at the airport. This is a key aspect in the evolution of the VHF data link system.

The initial list of airports for which the TMA and Airport service volume will have to be covered by a VDL Mode 2 VGS, can be derived from the list of European Airports which TMA is currently covered for ACARS communications thanks to an additional Airport/TMA dedicated VHF frequency in the SITA network [6]. This list is given in the table below.

Country	Suitable Locations for an initial VDL Mode 2 coverage of the TMA service volume
United Kingdom	London (Heathrow+Gatwick)
France	Paris (CDG+Orly)
Germany	Dusseldorf Frankfurt Hamburg Munich Berlin
Switzerland	Zurich
Netherlands	Amsterdam
Belgium	Brussels
Spain	Madrid

2.3.4.4 Specific “Airport Surface” Service volume

This last type of service volume is needed only for large TMAs covering several large airports.

In the ACCESS region, the only requirement for discriminating between TMA service volume and airport surface service volume is the Paris and London TMA, where a separate airport surface service volume for Roissy, Orly, Gatwick and Heathrow would make sense operationally, since it would be impossible to find one single site in London and Paris providing line-of-sight VDL communications with aircraft on the ground at either airports. This technical argument is further reinforced by the sheer size of these airports, and their strategic role as hubs, for both international traffic and national traffic.

At other airports, there is no requirement to provide surface service volume as distinct from TMA service volume.

2.3.5 VDL Mode Frequencies Requirements and Constraints

The VHF band 117.975 - 137 MHz is allocated to air/ground communications on an exclusive primary basis world wide (ITU, ICAO Annex 10).

Current international standards channelize the spectrum in 25 kHz increments for data applications. This arrangement yields 760 discrete channels, with the lowest assignable frequency at 118 MHz and the highest at 136.975 MHz.

Within the 117.975 - 137 MHz band, channels are allocated for different communications functions (as ATC, Flight test, AOC) on a regional basis.

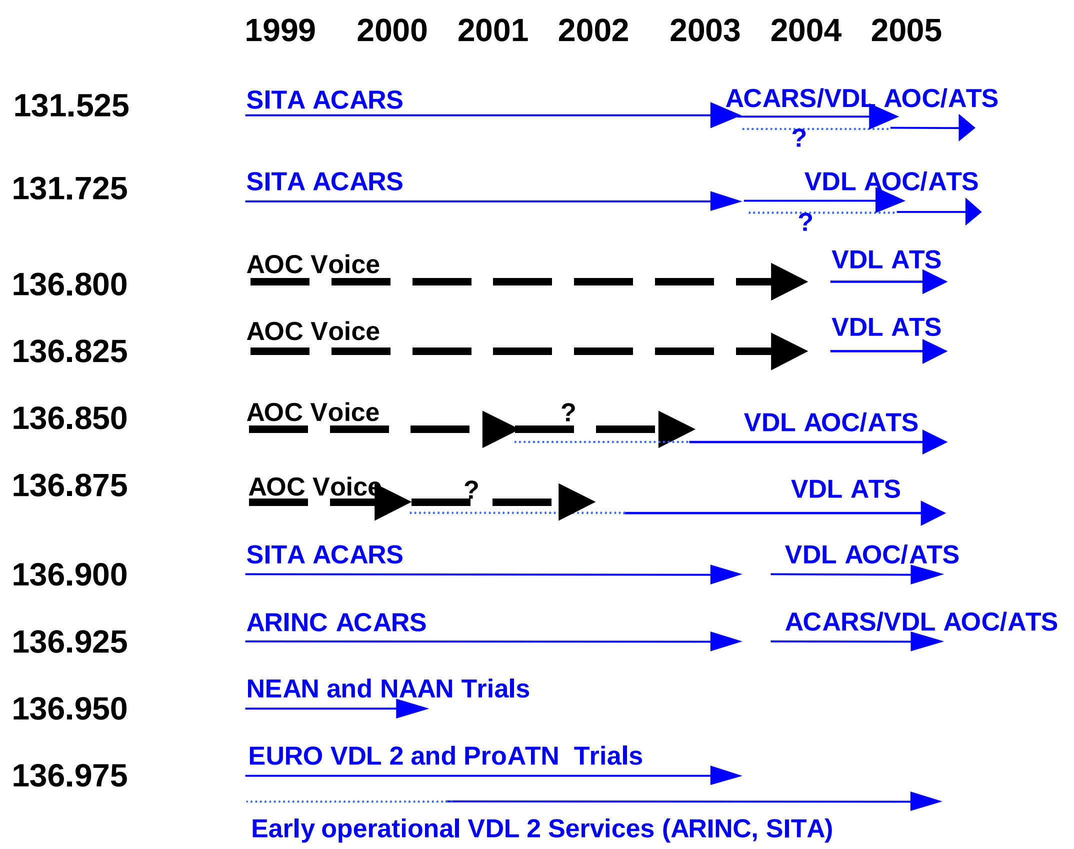
Among the VHF channels available for air/ground communications, most of them are allocated to voice communications. The channels reserved for air-ground VDL data link communications (exclusive use) are currently limited to the four upper channels (from 136.900 to 136.975 MHz) on a world wide basis. In the European region, these four channels have been allocated as follows by the Frequency Management Group (FMG):

1. channel 136.900: this channel has been allocated to SITA. SITA currently uses this channel as a terminal dedicated frequency for ACARS/VHF traffic in major airports, but should reallocate it to VDL Mode 2 traffic from 2003 onward.
2. channel 136.925: this channel has been allocated to ARINC. ARINC currently uses this channel for ACARS/VHF traffic, but should also reallocate it to VDL Mode 2 traffic from 2003 onward.
3. channel 136.950: this channel has been allocated to VDL Mode 4 validation.
4. channel 136.975: this frequency was reserved for the Common Signalling Channel (CSC). However, the current plans are to use this frequency for an early deployment of the VDL Mode 2 in Europe. This frequency is notably used for VDL Mode 2 pre-operational trials in the context of ProATN and EuroVDL projects. It is furthermore likely that the CSPs will be allowed to use that frequency for the early deployment of a VDL Mode 2 service in Europe.

In the first stages of VDL Mode 2 deployment it is unlikely that additional frequencies can be made readily available. Therefore, the baseline hypothesis is that:

1. the 136.975 frequency will be the only available frequency for the initial deployment because CSPs will not reallocate ACARS-used frequencies to VDL Mode 2 as this would worsen the existing ACARS limitations, at least in the first stages of the deployment.
2. in a second step (after 2003), as CSPs will be able to get back frequencies that were previously used for ACARS VHF, no more than 3 frequencies will be available for the the VDL Mode 2 deployment in Europe[1].
3. fortunately after around 2005, owing to the progressive introduction of 8.33 kHz voicelinks, more channels could be freed for providing the data link services and be assigned either to the ATSOs and/or the CSPs for VDL Mode 2 data link services provision.

The next figure outlines a likely availability of VDL frequencies in the European core area in the next years: the thick dashed arrows show 4 voice channels that may be used for VDL in the future, depending on the introduction of 8.33 kHz channel spacing.



[1] In fact it is likely that ARINC will be able to reuse its 136.925 channel only <u>after</u> 2003 because it is their only available ACARS frequency in Europe.

2.4 Communication Service Provider (CSP)-driven strategy for the VDL Mode 2 Deployment

2.4.1 Introduction

The CSP-driven strategy for the deployment of the VDL Mode 2 will primarily be based on the airlines requiring their communication service provider to implement or expand their air-ground data link system to meet their requirements, mainly for AOC.

Under this strategy the deployment of VDL Mode 2 depends on the needs of the airlines for AOC primarily, and possibly enabling the same service to be offered to ATS service providers for ATS data link services.

For AOC the main driving forces of the deployment scenario are:

- to ensure that the most ACARS-constrained service volumes are addressed first, in order to justify the investment to be made on behalf of AOC stakeholders,
- to take into account the ATSC data traffic flow as an additional source of revenue, yet not sufficient in itself to justify the deployment of a new infrastructure,
- to optimise the limitations to be set on the supplied QoS so as not to support those ATSC requirements having too long a Return On Investment (ROI) period.

Therefore, the philosophy of the deployment would be focused on service volumes, promising a faster ROI, according to AOC data traffic flows.

2.4.2 Deployment Scenario

The likely VDL Mode 2 deployment scenario for a CSP in Europe can be derived from the history and the current status of the deployment of the SITA ACARS VHF subnetwork in Europe.

⌦ *first step (1999-2001):*

It is reasonable to assume that the *first step* (from 1999 to 2001) of the deployment will be for a CSP to use the 136.975 channel as a general purpose (base) frequency providing general coverage of both airport, TMA and en-route service volume and to deploy the first VDL ground stations in those airports where the ACARS capacity limitations are most felt. This would imply the deployment of VDL ground stations in each of the main airports where SITA currently uses its VDL Mode 2 frequency (i.e. 136.900 MHz) to provide additional terminal traffic dedicated capacity [6].

Although the foreseen VDL Mode 2 coverage for that first step is built from the ACARS VHF situation in Europe where currently SITA has a dominant position, it can be assumed that an equivalent VDL Mode 2 coverage will be achieved by ARINC (using the same 136.975 channel), as that coverage (i.e., more or less the core area) is drawn by mere business considerations.

The initial VDL Mode 2 deployment will therefore results in the coverage of the core area around 2002 by different CSPs competing for the same airspaces and using the same frequency. At this stage, VDL Mode 2 networks will be mainly used for AOC/ACARS traffic and some pre-operational ATSC traffic.

That coverage can be deduced from the following list of the airports:

Country	First airports to be equipped with a VDL Mode 2 GRS
United Kingdom	London Heathrow London Gatwick
France	Paris CDG Paris Orly
Germany	Dusseldorf Frankfurt Hamburg Munich Berlin
Switzerland	Zurich
Netherlands	Amsterdam
Belgium	Brussels
Spain	Madrid

The resulting initial coverage, at an altitude of 20000 feet, is represented on Figure 1.

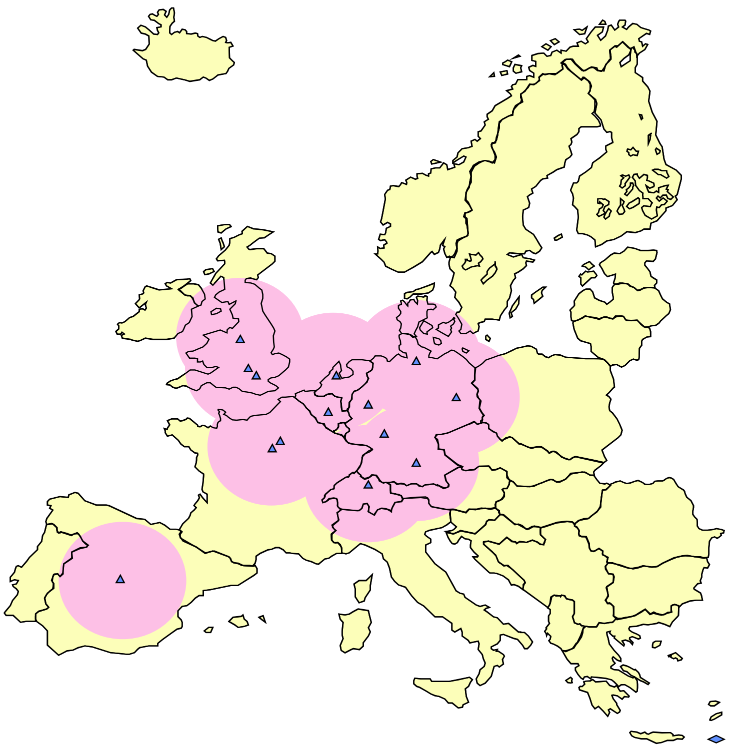


Figure 1

⌦ *second step (2001-2003):*

In a *second step* (2001-2003), while a second channel is not available for CSPs, it seems reasonable to assume that CSPs would extend the availability of their base VDL mode 2 coverage to cover other large airports and a larger European en-route airspace. It is assumed that this extended base coverage would not be very different from the coverage of the alternate en-route ACARS VHF infrastructure that has been deployed by SITA to circumvent the ACARS shortage experienced for en-route communications in the European Region [6].

The same 136.975 frequency will still be used by the CSPs in that period.

This would lead to the deployment of additional VDL Mode 2 VGS at the new locations presented in the next table.

In that period, VDL Mode 2 networks will continue to be mainly used for AOC/ACARS traffic, while some operational ATSC traffic will start to be carried over certain VDL Mode 2 subnetworks (due to the implementation of "local" ATC services).

Country	Locations for the second step of the VDL Mode 2 deployment
United Kingdom	Glasgow
France	Brest Bordeaux Toulouse Nice Lyon
Germany	Stuggart Cologne
Switzerland	Geneva
Spain	Barcelona
Ireland	Shannon
Norway	Oslo
Sweden	Stockholm
Denmark	Copenhagen
Austria	Vienna

The resulting coverage, at an altitude of 20000 feet, is represented on Figure 2.

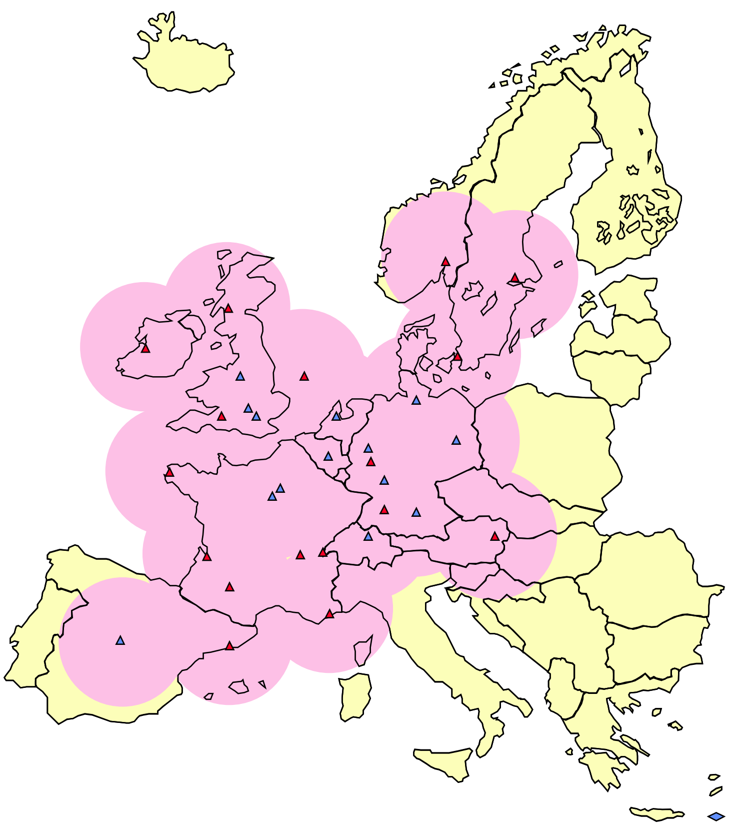


Figure 2

⌦ *third step (2003-2005):*

The geographical extension of the CSP base VDL Mode 2 coverage may then continue with the coverage of other airports and of other European airspace depending on the VHF ACARS shortage and possibly on the airline requirements which may be willing to develop new binary-oriented AOC applications requiring a generalization of the VDL Mode 2 coverage.

In that period, it is also likely that CSPs reuse one of their own previously ACARS frequencies for VDL Mode 2 in some locations, where this would help solve AOC/ACARS shortages (e.g., for SITA this would consist in replacing their VHF RGSs operating on the 136.900 MHz channel by VDL VGSs operating on the same frequency). This would result in the possible use of several VDL Mode 2 frequencies (up to 3) in Europe.

This *third step* (2003-2005) would then primarily be marked by the deployment of airport/TMA dedicated VDL Mode 2 VGS in the main airports, and operating on a new channel. The list of airport equipped with this new VGS is assumed to be same as the list of airports that where first equipped with VDL Mode 2 in step 1.

From this period, operational ATSC traffic will start to represent an increasing part of the overall traffic carried over VDL Mode 2 networks.

The resulting coverage, is depicted on Figure 3.

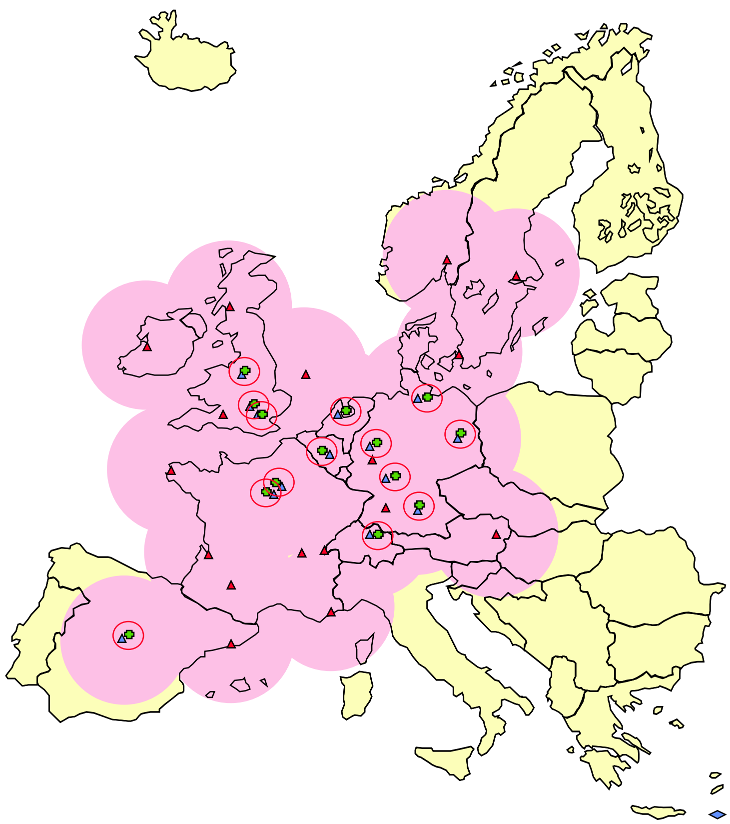


Figure 3

⌦ *fourth step (beyond 2005):*

This period could correspond to a phase where:

- due to the migration towards the 8.33KHz channel spacing for voice, additional VDL Mode 2 channels become available for the CSPs, and
- due to the increasing number of aircraft equipped with VDR, a shortage of the VDL Mode 2 channel capacity would be experienced in larger European airports.

This *fourth step* should include:

- the extension of the base coverage to other airports and other European areas
- the deployment of airport/TMA dedicated VDL Mode 2 VGS in regional airports, such as Toulouse, Nice, etc...
- and possibly, the splitting between TMA service volume and airport surface service volume in the Paris and London areas.

2.5 Air Traffic Service Provider (ATSP) Driven Strategy for the VDL Mode 2 Deployment

2.5.1 Introduction

The ATSOs strategy for the VDL Mode 2 deployment is based on the premise that the Air Traffic Service Organisations need to have full control for the design, implementation and operation of a VDL network to meet their safety responsibilities but also assuming that it is financially viable. This strategy must be justified by consideration of the cost, lack of visibility of a third party provider and limitations of a service provider. Given there is no compromise to safety, an ATSO could offer AOC but at a lower priority.

Other reasons for pursuing this strategy could be, for Air Traffic Management entities, to recoup their VDL infrastructure investment by entering the market of AOC data link services. Or it could also be based on the consideration that only an ATSO-controlled network deployment can meet the longer term needs of ATSC.

Under this strategy the emphasis would be :

- to optimise the design of the VDL network according to ATSC needs,
- for the VDL subnetwork to be deployed and operated either by the ATSO or by a third party independent of the Airlines
- to negotiate with Airlines to offer some costed AOC services.

This strategy is however believed to be realistic in the long term only. In the short term, for the initial deployment of the VDL Mode 2, it must be considered that an ATSO positioning itself as the VDL Mode 2 subnetwork service provider in its controlled airspace, would be under the pressure of the airlines requiring more subnetwork capacity for the AOC ACARS traffic. By contrast with the expected growth of AOC services, ATSC services require considerable international co-ordination and pre-operational validation which makes their deployment necessarily slow (as an example it took 3 to 4 years of pre-operational efforts to implement and validate the DCL and ATIS services over ACARS in only a few airports in France).

An additional (but related) aspect to be considered by the ATSO in the deployment of VDL Mode 2 is the migration of airborne avionics from ACARS to ATN, which could be performed in 2 steps, with a first step including the installation on board of a pre-ATN stack (CMU/ATSU without TP4, the Upper Layers and the ATN applications) for AOC purpose only, followed in a second stage by the implementation on board of the ATN services.

Lastly, it is assumed that the ATSOs will not neglect the advantages of an initial VDL Mode 2 deployment scenario promising a faster Return on Investment and therefore focused on the areas with a high volume of ACARS traffic.

The ATSOs would therefore likely concentrate first on the immediate airline requirements before enhancing the design of the VDL network according to ATSC needs.

A two phases process is foreseen ([2]), with each phase corresponding to an avionics upgrade. The first phase is primarily concerned with VDL Mode 2 introduction as ACARS replacement solution, but also sees the progressive development of a ground ATN Internet, the gaining of considerable in-service experience of the management of such an internet.

The second phase requires an FMS upgrade to support the full CNS/ATM applications and replacement of the current FANS-1/A generation of applications on board, and the operational commissioning of ATSC service on the ground.

2.5.2 Phase 1 VDL Mode 2 Introduction as ACARS Replacement Solution

The justification for phase one starting is the need to gain increased capacity through an ACARS upgrade. Because of aircraft re-equipage timescales, it must also include the introduction of the ICAO ATN. Phase one concludes when a ground ATN Internet has been established, a critical mass of aircrafts have been upgraded to VDL Mode 2 (with CMU/ATSU upgrade).

On the ground, it is assumed that the scenarios for the deployment by ATSO of a VDL Mode 2 infrastructure during this phase would be very similar to those described as steps 1 and 2 in section 2.4.2. The possible slight difference is that local or European initiatives may lead some ATSOs to deploy more quickly a few additional VDL Mode 2 VGSs on their territory so as to have the ability to perform pre-operational validation of ATSC services (e.g. in step 1, ProATN VDL Mode 2 VGS in Toulouse, Euro VDL VGS in Geneva, Rome and possibly Nice; in step 2 possible additional VGS in Italy, Spain and Portugal)

2.5.3 Phase 2 Introduction of CNS/ATM-1 Applications

The VDL Mode 2 subnetwork will have been developed in support of AOC use and FANS-1/A. It is now ready to support the next generation of CNS/ATM applications.

The phase two really starts when the FMS and the ATC Centres are upgraded to comprise the implementation of the CNS/ATM applications, and concludes with the complete replacement of ACARS/FANS-1(A) equipment and the withdrawal of services based on this equipment.

During this phase the sudden increase of ATSC traffic, and the requirement to operate the VDL Mode 2 below its maximum capacity in order to fulfil the ATSC transit delay requirements, may lead to a shortage of the capacity of the subnetwork in the core area.

As for the CSP-driven VDL Mode deployment in steps 3 and 4 (see section 2.4.2), it is assumed that ATSOs would counter the capacity limitation problems with the use of additional channels and the splitting between en-route service volume, TMA/airport service volume and airport-only service volume in major airports in the core area.

The scenarios for the extension by ATSO of the initial VDL Mode 2 infrastructure would therefore be very similar to those described as steps 3 and 4 in section 2.4.2. A possible difference is that ATSOs in low traffic density area (e.g. eastern Europe) may not be very advanced in data link service implementation programs, and hence may not implicate themselves in the deployment of a VDL Mode 2 infrastructure which would not bring many benefits and which, due to the low volume of AOC and ATSC traffic, would not be very cost effective.

2.6 Institutional Issues

This section gives a brief overview of some of the institutional issues that need to be considered for either of the strategies identified in the study.

2.6.1 Communication Provision

As the safety and security of air traffic within a State and its airspace is the responsibility of the State or appointed representation (i.e. the ATSO), this responsibility will apply to the introduction of VDL Mode 2 for ATS services[5]. Under both scenarios used in the study, VDL Mode 2 for safety related ATSC has to be regulated to ensure that the Quality of Service required to support safety-related ATS can be meet.

When the entire communications chain is under the control of an ATSO including design, implementation and operation, it is possible to ensure an appropriate level of QoS is achieved. The more elements of this chain that are outside direct control (e.g. ground-ground network connections) the less visibility the client has of the provisions to meet requirements. Therefore a Service Level Agreement is the usual way to try to ensure the CSP will provide the required QoS. Whilst a SLA may be a useful contractual document, achieving this required QoS may be difficult all the time or it may be very costly.

2.6.2 Liability

The need to cover liability arises from a potential malfunction in the VDL chain leading to injury, death, or financial loss. Blame for the liability can be attributable to negligence or failure to take proper precautions. In the case of VDL implementation there are various conditions in which liability can arise.

1. total loss of communication
2. corruption of message
3. reduced communications performance
4. incorrect delivery of a message
5. Loss of revenue due any of the above

In the case of the CSP-driven scenario, these must be covered by appropriate clauses in the contract between the Service Provider and the ATSOs. However, it may be difficult for the ATSOs legally to devolve responsibility to the Service Provider. Very careful consideration must be given to the issue of liability.

2.7 Future Trends

The two strategies identified in the study are driven by different forces: the ATSP-driven strategy can be justified by political factors (ATSOs keep control of the VDL networks) whereas the CSP-driven strategy is based on economic factors mainly related to AOC needs.

However the current trend for VDL is that, apart from ATS A/G data communication, the implementation of VDL Mode 2 in Europe is mainly driven by AOC applications. They promise early benefits for aircraft operators and offer large growth potentials compared with the increasingly saturated ACARS-system. In contrast to the ATS-applications, the AOC-applications are ready to be used in the short time frame, including all elements of the data communication end-to-end path. Resulting from this, the CSPs are under pressure to provide the VDL Mode 2 link in order to enable the customers (airlines) to realise their prospected, very obvious appearing cost savings. Looking to European ATSOs, it seems that the usage of VDL Mode 2 for the exchange of ATS-messages may still take a while. Reasons for that are not seen in the availability of necessary telecomm infrastructure or any delays of standardisation processes. The big issue is much more the update to be applied to legacy processing systems or even the integration of datalink-service compatibility into new FDPS and other processing systems. The actions to be taken here are extremely timeconsuming and demand all kind of resources.

The bottomline is that CSPs have an earlier need to implement the VDL Mode 2 infrastructure compared to the ATSOs, although they also intend to use VDL Mode 2 to carry their A/G messages related to ATS datalink services.

Therefore the resulting situation for the provision of a future VDL Mode 2 subnetwork in the ACCESS area is likely to be one of the following[2]:

1. All CSPs provide single subnetworks and market their bandwidth to the airspace users and to the ATSOs (CSP-driven strategy),
2. CSPs and ATSOs provide single subnetworks, CSPs market their bandwidth to the airlines, ATSOs provide ATS-datalink services using their network (ATSP-driven strategy).

All mentioned alternatives imply multiple questions in terms of institutional issues, further legal issues, QoS-questions and many more. Due to the mentioned difference in the short term demand of the A/G-link availability with respect to CSPs and ATSOs, all stakeholders today face the need for selecting one of the future scenarios mentioned above.

However, in the absence of an affirmed and coordinated move from ATSOs to develop a European-wide ATSO-operated VDL Mode 2 coverage, the first alternative appears to be the most probable as it can be seen as the result of the current trends affecting the VDL Mode 2 deployment in Europe. Conversely, as there is a real and urgent need for CSPs to circumvent existing AOC ACARS VHF shortages, it appears that CSPs will rapidly deploy VDL Mode 2 VGSs across the core area (by 2002), no matter how and when ATSOs will develop their ATN-based ATS datalink services.

Assuming that situation will go on, it can therefore be expected that the CSP-driven strategy will drive the VDL Mode 2 deployment in Europe, where two competing CSPs will provide a similar coverage (initially using the same single frequency). That coverage being mainly provided by CSPs, the question of the deployment of the ATN ground infrastructure using that VDL Mode 2 infrastructure for ATSC needs remains an open issue (e.g., who will own or operate the a/g BISs, ATN router siting, etc.).

[2] A third alternative could be imagined whereby a new non-profit body, equally owned and regulated by CSPs and ATSOs, would operate a VDL Mode 2 subnetwork covering a large geographical area (AOC-related bandwith would be marketed by CSPs). This alternative may be seen as a combination of both ATSP- and CSP-strategies; however it cannot be retained as a likely solution in the absence of tangible elements supporting that scenario (this would certainly require further investigations that are out of the scope of the ACCESS study).

3. Deployment Scenarios for AMSS

3.1 Introduction

It should be recognised that AMSS is unlikely to be the preferred air/ground subnetwork in the core European area since other subnetworks (e.g. VDL, Mode S) will be supported in the region and are likely to provide a more cost effective capability. The use of AMSS may be restricted to fringe areas where existing infrastructure is limited such as the Mediterranean or Eastern Europe. It may also provide a backup capability to support the preferred air/ground subnetworks under failure conditions.

It should also be recognised that, currently, satellite communications equipment is only being fitted to long haul aircraft such as the Boeing 747-400 or the Airbus A340 and is primarily being installed to support passenger cabin communications. At present, short haul aircraft such as those operating within the core area of Europe do not possess an AMSS capability. This situation may change with the availability of new satellite services which offer the potential of smaller and cheaper avionics such as Inmarsat Aero-I and the future LEO/MEO systems such as Iridium. However, the impact of such services is still not predictable.

The satellite system currently used to provide Aeronautical services is the Inmarsat Aero-H system which uses four geostationary satellites to provide global coverage (except for the polar regions). The core European area has overlapping coverage from three of the four satellites (Atlantic Ocean Region East and West [AORE, AORW] and Indian Ocean Region [IOR]). Aircraft communicate with the ground via Ground Earth Stations (GES). There are a number of GESs available to each satellite and these are operated by local PTTs who are known as Inmarsat signatories. In general, these Inmarsat signatories are grouped into consortia known as “satellite service providers” who offer a global communications service to users such as airlines. The users choose their satellite service provider based on purely commercial considerations mainly to suit their passenger cabin requirements. For ATS purposes it will therefore be necessary to make suitable arrangements with **all** the satellite service providers (currently three) in order to ensure that it is possible for ATC to communicate with **all** satcom equipped aircraft. that need to use the service.

3.2 Satellite Service Providers

3.2.1 Overview

Three satellite service providers currently provide Aeronautical services via the Inmarsat satellite system. These are:

Satellite Aircom
Skyphone
Skyways Alliance

Further details are given in the following sections.

3.2.2 Satellite Aircom

The members of the Satellite Aircom consortium are :

France Telecom
SITA
Teleglobe Canada
Telstra (Australia) .

Ground Earth Stations used by aircraft for the Aero-H service are:

AORE	Aussaguel (France)
AORW	Aussaguel (France), Weir (Canada)
IOR	Perth (Australia)
POR	Perth (Australia), Niles Canyon (USA).

In addition, following the launch of the Inmarsat Aero-I service in May 1998, Satellite Aircom have recently announced that they are providing a global Aero-I service using the following GESs only:

AORE, AORW	Aussaguel (France)
IOR, POR	Perth (Australia)

3.2.3 Skyphone

The members of the Skyphone consortium are :

British Telecom
Telenor
Singapore Telecom

Ground Earth Stations used by aircraft for the Aero-H service are:

AORE	Goonhilly (UK), Eik (Norway)
AORW	Goonhilly (UK)
IOR	Eik (Norway)
POR	Sentosa (Singapore)

Standby GESs are available at Eik (for AORW) and Sentosa (for IOR). These would be activated if a failure occurs in the main GES serving those satellite regions.

The Aero-I service is not currently supported by the Skyphone consortium.

3.2.4 Skyways Alliance

The members of the Skyways Alliance consortium are :

Comsat
KDD
The Communications Authority of Thailand
Korea Telecom
Telecom Italia .

Ground Earth Stations used by aircraft for the Aero-H service are:

AORE	Fucino (Italy)
AORW	Southbury (USA)
IOR	Yamaguchi (Japan), Nonthaburi (Thailand), Fucino (Italy)
POR	Santa Paula (USA), Yamaguchi (Japan), Kumsan (Korea).

The Aero-I service is not currently supported by the Skyways Alliance consortium.

3.3 Services Available

3.3.1 Aero-H

The satcom packet data services available from the Aero-H service fall into two categories.

The first of these (known as Data-2) is a simplified service that lacks network layer functions and has no routing capability. Its main function is to support existing character oriented ACARS/AIRCOM type services. However, in conjunction with the special bit to character oriented protocols defined in ARINC 622, it can be used to transmit bit oriented applications (such as ADS and CPDLC) over the existing character oriented ARINC and SITA networks. This capability is used in the FANS-1 and FANS-A systems currently being marketed by Boeing and Airbus for the 747-400 and A340 aircraft respectively.

The second service (known as Data-3) is fully compliant both with ISO 8208 and the ICAO SARPs for AMSS. Data-3 is required to support the ICAO SARPs for the ATN and has been available since 1995. Trials such as ADS EUROPE, ProATN and EOLIA have all used the Data-3 service which was the first air/ground subnetwork fully compliant with the ICAO ATN SARPs to be available.

Two packet data rates are available using the Aero-H service, namely 600 bps or 10.5 kbps.

It is worth noting that AMSS also provides a circuit mode voice and data capability. The circuit mode data is designed for passenger cabin applications such as PC connection and fax and is not intended to be used for safety critical services such as ATC. The voice service currently uses a 9600 bps vocoder; this is currently being upgraded to a 4800bps vocoder as part of the latest Aero-H+ service.

3.3.2 Aero-I

Inmarsat introduced the Aero-I service in May 1998. The prime advantage that this service offers is for voice. Aero-I uses the spot beam capability of the Inmarsat 3 satellites which reduces the power requirements for the aircraft/satellite links and thus permits a considerable reduction in the size, weight, power requirements and cost of the AES avionics. The spot beams have been defined to cover the major land masses such as Europe and oceanic areas where dense traffic is expected, such as the North Atlantic (NAT).

The antenna used is much smaller than Aero-H and it is believed that it will make the use of satcom feasible (and cost effective) on a much wider range of narrow bodied and smaller aircraft. However, since there is little experience with the use of Aero-I to date this assumption has not yet been confirmed.

The Aero-I service still uses the satellite global beam for data transmissions Three packet data rates will be available using the Aero-I service, namely 600 bps or 1.2 kbps with a future upgrade to 4.8 kbps planned.

It is worth noting that the major advantages of Aero-I lie in the size, weight and reduction in cost of the avionics together with some reduction in voice charges due to the reduced power requirements on the satellite links. Aero-I still uses the global beam for packet data so, at present, the advice from service providers is that it is unlikely that there will be any reduction in data charges ($/kbit) associated with its use.

3.4 European AMSS Deployment Scenarios

3.4.1 Introduction

For operation in the core European area, it is likely that access will be required to aircraft mainly connected via the AORE and IOR satellites. Access to the AORW satellite may also be required, particularly for aircraft in the Western part of the core area (e.g. over the UK - westbound flights from Heathrow in particular). Trials experience to date has shown that AES swaps between satellites do not occur at predictable positions and are effectively random. This is because the algorithms used by the AES to dictate which satellite to use are designed to ensure that the maximum satellite gain is available to support the multiple (5 voice and one data) channels available from the AES.

Terrestrial ground data communications between ATC centres and the GESs can be handled using standard X.25 packet switched ground networks. For example, current trials are using the BT Global Network Service (GNS), the France Telecom Transpac service and the SITA Mega Transport Network (MTN).

It is therefore envisaged that X.25 terrestrial networks will be used to connect the satellite GESs to the ATN Routers (wherever the latter are installed). Connections to GESs from all three service providers covering the AORE and IOR satellite regions will be required and it is recommended that access to AORW should also be available to Centres in the western part of the core European area.

Hence, technically, there are few problems in implementing the necessary interconnections to obtain access to the satellite sub-network. However, the detailed definition of this infrastructure must be based on an operational scenario that defines the role of satellite communications in European airspace since this could affect the quality of service required from the subnetwork.. The links to some ATC Centres which need to rely on use of satcom may be more important and critical than those to other Centres where satcom is not being used as a primary communications medium but is only required for backup. Also, as mentioned in 1.1.3, it should be remembered that at present only long haul aircraft (plus some business jets) are being fitted with a satcom capability although this may change in future with the introduction of satellite systems such as Inmarsat Aero-I and Iridium.

3.4.2 Deployment Possibilities

It would appear that three deployment scenarios are possible, the actual deployment depending upon the number of ATC centres that wish to have access to AMSS and more importantly the willingness of ATSOs to depend on other ATSOs to assist in the provision of their ATC Service. The three options are descibed and illustrated in the following sections.

3.4.2.1 Scenario 1 - Complete Interconnectivity.

Each State would provide their own ATN A/G BIS and access to the AMSS subnetwork. As stated in section 1.1.4, it is the airlines that select which of the Satellite Service Providers they will use for the provision of ATC. This implies that each State requiring access to the AMSS subnetwork will need to have access to all three service providers via direct connections to the ground network of each of the service providers. An illustration of this topology is shown in Figure 1.

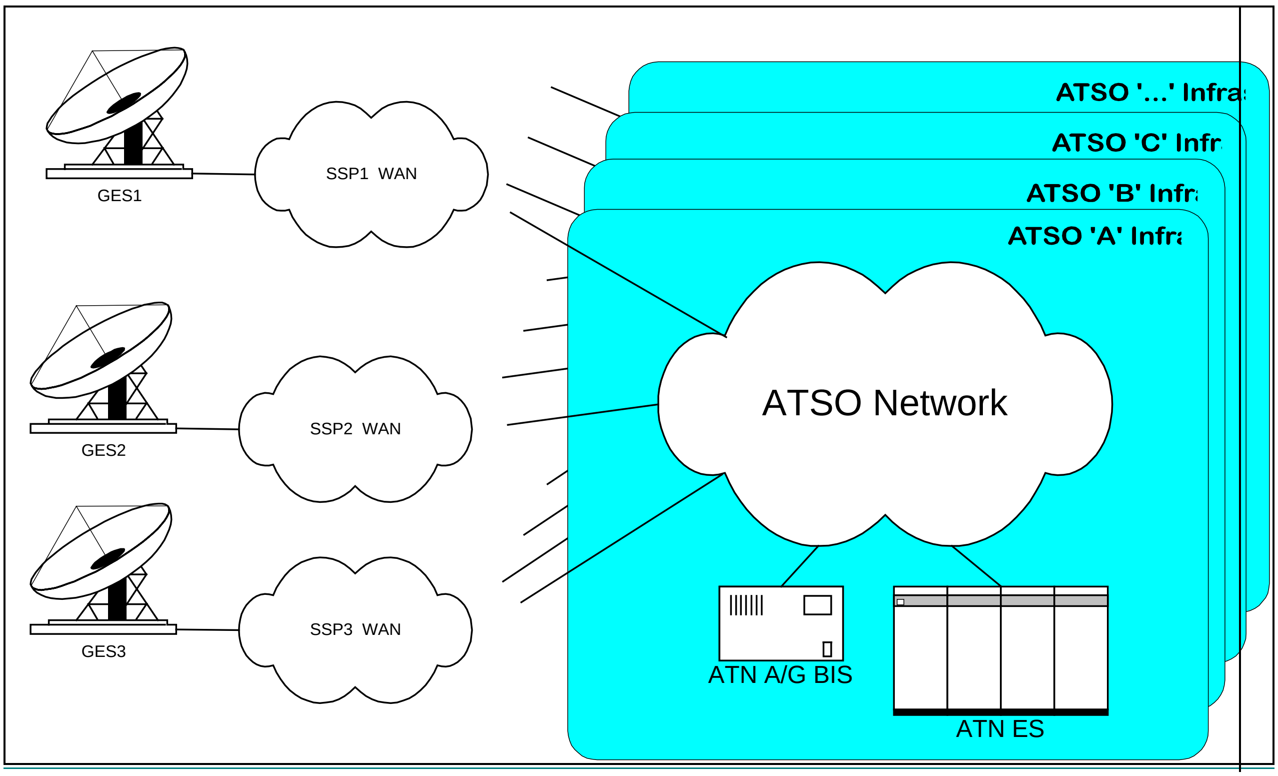


Figure 4 - AMSS provision with total interconnectivity

The advantages of this topology are:

- Each ATSO arranges and manages its own AMSS provision.
- The packet transit times are likely to be as short as possible because of the direct SSP WAN connections.
- Billing is more simply as each ATSO can pay directly for the traffic it is responsible for.

The disadvantages of this topology are:

- Airlines would need to hold and manage many A/G BIS addresses for logon purposes and change A/G BIS more frequently.
- The overall cost of the internetwork rises as each ATSO owns A/G BISs and needs multiple lines to the SSP WANs.

3.4.2.2 Scenario 2 - A/G BIS per GES.

Those States within which a GES is operated would provide an ATN A/G BIS to service all the connections via that GES. The Ground ATN Internet would be used to distribute the a/g data from these A/G BISs to the destination ESs. This is illustrated in Figure 2.

The advantages of this topology are:

- Airlines would need to hold and manage very few BIS addresses and would have infrequent A/G BIS changes.
- Fewer A/G BISs and bearer circuits are required.

The disadvantages of this topology are:

- States without GESs will need to reply on the States with GESs for their AMSS service.
- Billing is more complicated as cross charging will be necessary between the ATSOs.
- The packet transit times are likely to be non-optimal because of the indirect SSP WAN connections.
- The limited number of A/G BISs could increase the possibility of failure.
- Each of the A/G BISs will need to be more powerful as the same volume of data traffic will be concentrated through fewer routers.

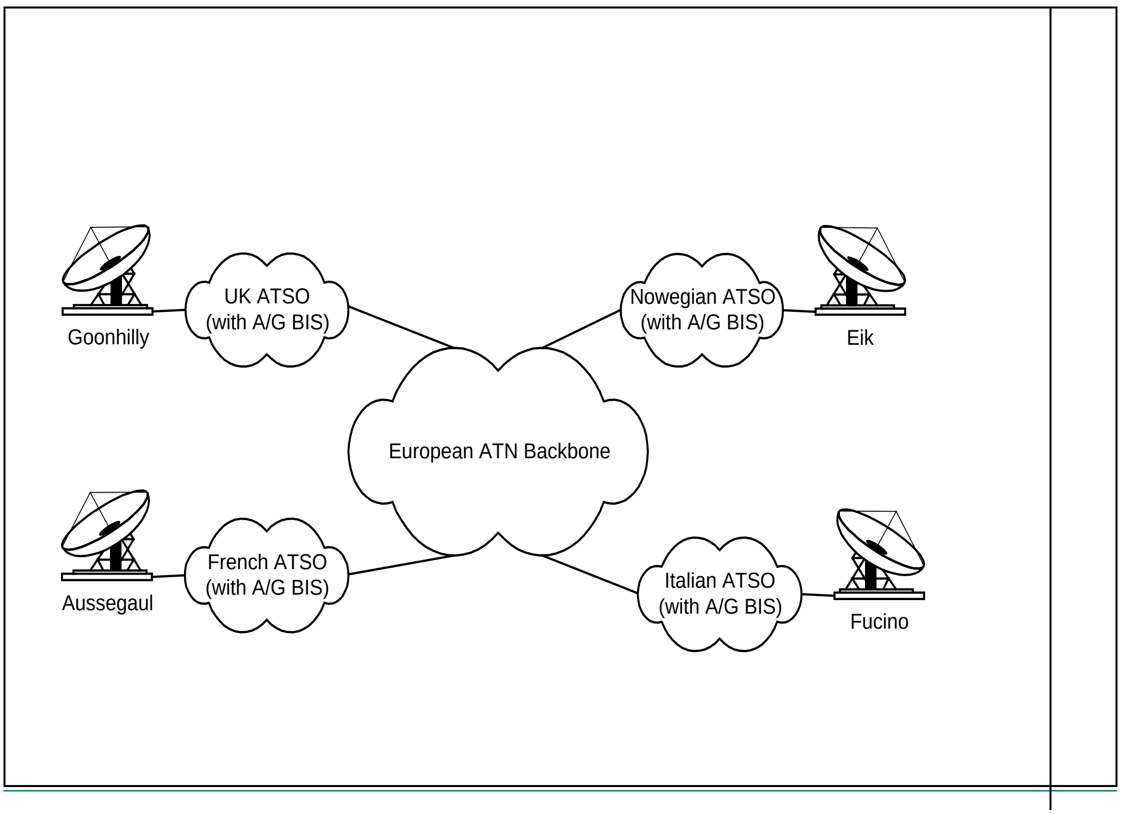


Figure 5 - AMSS Provision with one A/G BIS per GES

3.4.2.3 Scenario 3 - A/G BIS per AMSS Operator.

This is very similar to Scenario 2. Those States within which an AMSS Operator is based would provide an ATN A/G BIS to service all the connections via that company. A variation would be that the AMSS Operators themselves may provide the A/G BISs. The Ground ATN Internet would be used to distribute the a/g data from these A/G BISs to the destination ESs. This is illustrated in Figure 3.

The advantages of this topology are:

- Airlines would need to hold and manage very few BIS addresses and would have infrequent A/G BIS changes.
- Fewer A/G BISs and bearer circuits are required.

The disadvantages of this topology are:

- States without GESs will need to rely on the States with GESs for their AMSS service.
- Billing is more complicated as cross charging will be necessary between the ATSOs.
- The packet transit times are likely to be non-optimal because of the indirect SSP WAN connections.
- The limited number of A/G BISs could increase the possibility of failure.
- Each of the A/G BISs will need to be more powerful as the same volume of data traffic will be concentrated through fewer routers.

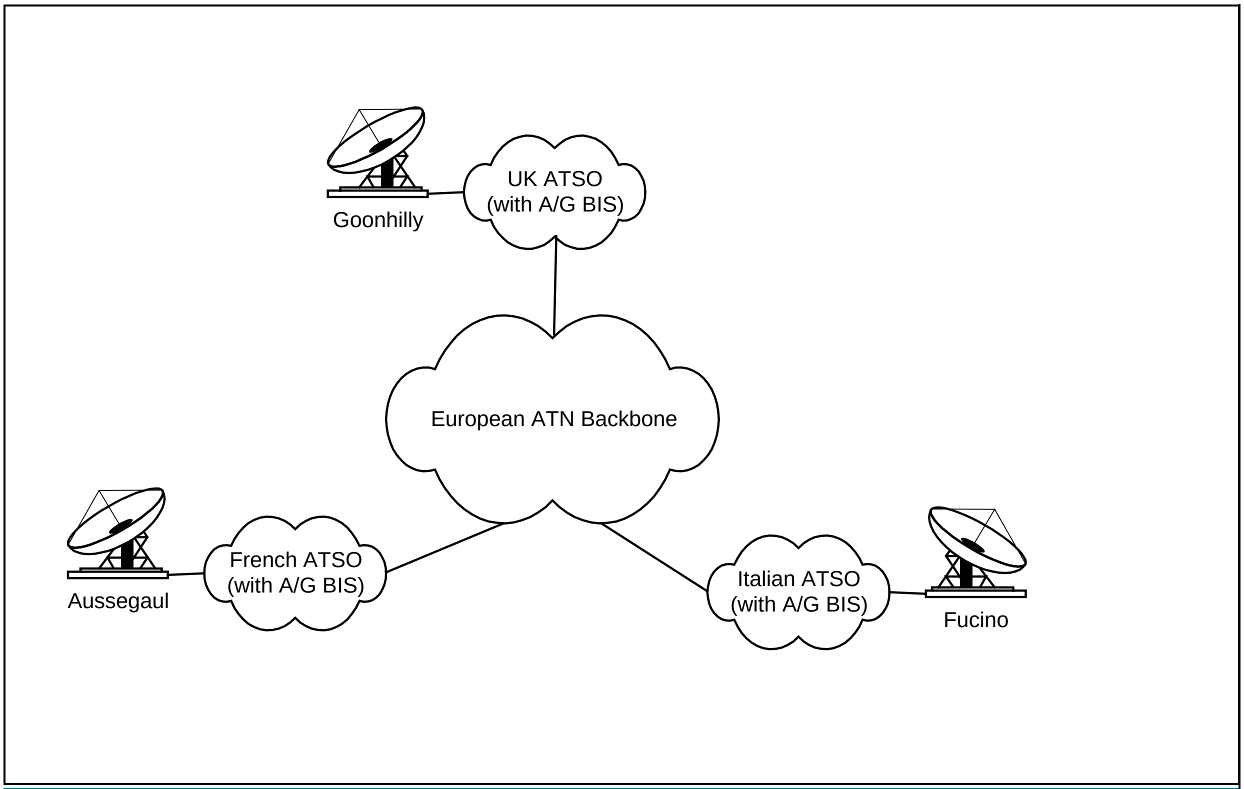


Figure 6 - AMSS Provision with one A/G BIS per AMSS Operator.

3.5 Future Trends

In future, it is likely that various competing LEO/MEO satellite systems which are currently under development will become available and these may be proposed for aeronautical use. In general, these Next Generation Satellite Systems (NGSS) are being designed to support the use of handheld mobile telephones and not primarily for safety critical packet data.

The current situation is that, of the NGSS currently under development, Iridium (LEO) have declared that they will be offering an aeronautical safety service from April 1999. Data and voice will be available and the planned data rate is 2.4 kbps. ICO have also indicated that they will offer an aeronautical service, but only for passenger cabin applications, not for ATS.

Other NGSS providers such as Globalstar have not yet declared their intention and it is believed that Boeing are also involved in a proposed aeronautical service but this will not be available until around 2005..

The common factor between all these NGSS is that none of them will be a system dedicated only to ATS; in every case ATS will just be one user and will generate a relatively small proportion of the total system traffic. All of these individual systems will be proprietary and it will be necessary for the ICAO standardisation process to operate at a very high, generic level rather than preparing detailed SARPs similar to those for AMSS which were developed to reflect the Inmarsat system. The precedent for this has now been created following the recent approval of the HFDL SARPs at AMCP/5 in April.

In all cases,. ATS providers will need to agree service level agreements with the satellite service provider to ensure the necessary quality of service is obtained. Historically, ATS providers have not taken this approach so it may be a painful learning experience!

The architecture of the NGSS sytems are still under definition and it may be necessary to interface to the satellite system via a gateway.

GLOSSARY

ACARS	Aircraft Communications and Reporting System
ADS	Automatic Dependent Surveillance
AMSS	Aeronautical Mobile Satellite Service
AOC	Aeronautical Operational Communications
AORE	Atlantic Ocean Region (East)
AORW	Atlantic Ocean Region (West)
ARINC	Aeronautical Radio Inc.
ATC	Air Traffic Control
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
ATSC	Air Traffic Service Communications
ATSO	Air Traffic Service Organisation
ATSP	Air Traffic Service Provider
BT	British Telecom
CNS	Communications, Navigation and Surveillance
CPDLC	Controller-Pilot Data Link Communications
CSP	Communication Service Provider
FANS	Future Air Navigation System
GES	Ground Earth Station
GNS	Global Network Services
HFDL	High Frequency Data Link
ICAO	International Civil Aviation Organisation
IOR	Indian Ocean Region
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
NAT	North Atlantic
NATS	National Air Traffic Services
NGSS	Next Generation Satellite Systems
POR	Pacific Ocean Region
PTT	Public Telephone & Telegraph
SARPs	Standards and Recommended Practices
SITA	Société Internationale Télécommunications Aéronautique
SLA	Service Level Agreement
SSP	Satellite Service Provider
TMA	Terminal Manoeuvering Area
VDL	VHF Data Link
VDR	VHF Digital Radio
VHF	Very High Frequency